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Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains

Methodology, Input Data and Comparisons to Previous Results for Ten Test Sites

Prepared by D. L. Bernreuter, J. B. Savy, R. W. Mensing, J. C. Chen

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Prepared for
U.S. Nuclear Regulatory Commission

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Abstract

The EUS Seismic Hazard Characterization Project (SHC) is the outgrowth of an earlier study performed as part of the U.S. Nuclear Regulatory Commission's (NRC) Systematic Evaluation Program (SEP). The objectives of the SHC were: (1) to develop a seismic hazard characterization methodology for the region east of the Rocky Mountains (EUS), and (2) the application of the methodology to 69 site locations, some of them with several local soil conditions. The method developed uses expert opinions to obtain the input to the analyses. An important aspect of the elicitation of the expert opinion process was the holding of two feedback meetings with all the experts in order to finalize the methodology and the input data bases. The hazard estimates are reported in terms of peak ground acceleration (PGA) and 5% damping velocity response spectra (PSV).

A total of eight volumes make up this report which contains a thorough description of the methodology, the expert opinion's elicitation process, the input data base as well as a discussion, comparison and summary volume (Volume VI).

Consistent with previous analyses, this study finds that there are large uncertainties associated with the estimates of seismic hazard in the EUS, and it identifies the ground motion modeling as the prime contributor to those uncertainties.

The data bases and software are made available to the NRC and to public uses through the National Energy Software Center (Argonne, Illinois).

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Foreword

The impetus for this study came from two unrelated needs of the Nuclear Regulatory Commission (NRC). One stimulus arose from the NRC funded "Seismic Safety Margins Research Programs" (SSMRP). The SSMRP's task of simplified methods needed to have available data and analysis software necessary to compute the seismic hazard at any site located east of the Rocky Mountains which we refer to as the Eastern United States (EUS) in a form suitable for use in probabilistic risk assessment (PRA). The second stimulus was the result of the NRC's discussions with the U.S. Geological Survey (USGS) regarding the USGS's proposed clarification of their past position with respect to the 1886 Charleston earthquake. The USGS clarification was finally issued on November 18, 1982, in a letter to the NRC, which states that:

> "Because the geologic and tectonic features of the Charleston region are similar to those in other regions of the eastern seaboard, we conclude that although there is no recent or historical evidence that other regions have experienced strong earthquakes, the historical record is not, of itself, sufficient ground for ruling out the occurrence in these other regions of strong seismic ground motions similar to those experienced near Charleston in 1886. Although the probability of strong ground motion due to an earthquake in any given year at a particular location in the eastern seaboard may be very low, deterministic and probabilistic evaluations of the seismic hazard should be made for individual sites in the eastern seaboard to establish the seismic engineering parameters for critical facilities."

Anticipation of this letter led the Office of Nuclear Reactor Regulation to jointly fund a project with the Office of Nuclear Regulatory Research. The results were presented in Bernreuter et. al. (1985), and the objectives were:

1. to develop a seismic hazard characterization methodology for the entire region of the United States east of the Rocky Mountains (Referred to as EUS in this report).

2. to apply the methodology to selected sites to assist the NRC staff in their assessment of the implications in the clarification of the USGS position on the Charleston earthquake, and the implications of the occurrence of the recent earthquakes such as that which occurred in New Brunswick, Canada, in 1982.

The methodology used in that 1985 study evolved from two earlier studies LLNL performed for the NRC. One study, Bernreuter and Minichino (1983), was part of the NRC's Systematic Evaluation Program (SEP) and is simply referred hereafter to as the SEP study. The other study was part of the SSMRP.

At the time (1980-1985), an improved hazard analysis methodology and EUS seismicity and ground motion data set were required for several reasons:

- o Although the entire EUS was considered at the time of the SEP study, attention was focused on the areas around the SEP sites--mainly in the

Central United States (CUS) and New England. The zonation of other areas was not performed with the same level of detail.

- The peer review process, both by our Peer Review Panel and other reviewers, identified some areas of possible improvements in the SEP methodology.

- Since the SEP zonations were provided by our EUS Seismicity Panel in early 1979, a number of important studies have been completed and several significant EUS earthquakes have occurred which could impact the Panel members' understanding of the seismotectonics of the EUS.

- Our understanding of the EUS ground motion had improved since the time the SEP study was performed.

By the time our methodology was firmed up, the expert opinions collected and the calculations performed (i.e. by 1985), the Electric Power Research Institute (EPRI) had embarked on a parallel study.

We performed a comparative study, Bernreuter et. al. (1987), to help in understanding the reasons for differences in results between the LLNL and the EPRI studies. The three main differences were found to be: (1) the minimum magnitude value of the earthquakes contributing to the hazard in the EUS, (2) the ground motion attenuation models, and (3) the fact that LLNL accounted for local site characteristics and EPRI did not. Several years passed between the 1985 study and the application of the methodology to all the sites in the EUS. In recognition of the fact that during that time a considerable amount of research in seismotectonics and in the field of strong ground motion prediction, in particular with the development of the so called random vibration or stochastic approach, NRC decided to follow our recommendations and have a final round of feedback with all our experts prior to finalizing the input to the analysis.

In addition, we critically reviewed our methodology which lead to minor improvements and we also provided an extensive account of documentation on the ways the experts interpreted our questionnaires and how they developed their answers. Some of the improvements were necessitated by the recognition of the fact that the results of our study will be used, together with results from other studies such as the EPRI study or the USGS study, to evaluate the relative hazard between the different plant sites in the EUS.

This report is comprised of eight volumes:

Volume I provides an overview of the methodology we developed as part of this project. It also documents the final makeup of both our Seismicity and Ground Motion Panels, and documents the final input from the members of both panels used in the analysis. Comparisons are made between the new results and previous results.

Volumes II to V provide the results for all the active nuclear power plant sites of the EUS divided into four batches of approximately equal size and of sites roughly located in the four main regions of the EUS. A regional discussion is given in each of Vols. II to V.

Volume VI gives some important sensitivity studies, in particular the sensitivity of the results to correction for local site conditions and G-Expert 5's ground motion model. Volume VI also contains a summary of the results and provides comparisons between the sites within a common region and for sites between regions.

Volume VII contains unaltered copies of the ten questionnaires used from the beginning of the 1985 study to develop the complete input for this analysis.

After the bulk of the work was completed and draft reports for Vols. I-VII were written, additional funding became available.

Volume VIII contains the hazard result for the 12 sites which had some structures founded on shallow soil. These results supplement the results given in Vols. II to V where only the primary soil condition at the site was used.

List of Abbreviations and Symbols

A	Symbol for Seismicity Expert 10 in the figures displaying the results for the S-Experts
ALEAS	Computer code to compute the BE Hazard and the CP Hazard for each seismicity expert
AM	Arithmetic mean
AMHC	Arithmetic mean hazard curve
B	Symbol for Seismicity Expert 11 in the figures displaying the results for the S-Experts
BE	Best estimate
BEHC	Best estimate hazard curve
BEUHS	Best estimate uniform hazard spectrum
BEM	Best estimate map
C	Symbol for Seismicity Expert 12 in the figures displaying the results for the S-Experts
COMAP	Computer code to generate the set of all alternative maps and the discrete probability density of maps
COMB	Computer code to combine BE hazard and CP hazard over all seismicity experts
CP	Constant percentile
CPHC	Constant percentile hazard curve
CPUHS	Constant percentile uniform hazard spectrum
CUS	Central United States, roughly the area bounded in the west by the Rocky Mountains and on the east by the Appalachian Mountains, excluding both mountain systems themselves
CZ	Complementary zone
D	Symbol for Seismicity Expert 13 in the figures displaying the results for the S-Experts
EPRI	Electric Power Research Institute
EUS	Used to denote the general geographical region east of the Rocky Mountains, including the specific region of the Central United States (CUS)

g	Measure of acceleration: 1g = 9.81m/s/s = acceleration of gravity
G-Expert	One of the five experts elicited to select the ground motion models used in the analysis
GM	Ground motion
HC	Hazard curve
I_o	Epicentral intensity of an earthquake relative to the MMI scale
I_s	Site intensity of an earthquake relative to the MMI scale
LB	Lower bound
LLNL	Lawrence Livermore National Laboratory
M	Used generically for any of the many magnitude scales but generally m_b, $m_b(Lg)$, or M_L.
M_L	Local magnitude (Richter magnitude scale)
M_b	True body wave magnitude scale, assumed to be equivalent to $m_b(Lg)$ (see Chung and Bernreuter, 1981)
$m_b(Lg)$	Nuttli's magnitude scale for the Central United States based on the Lg surface waves
M_S	Surface wave magnitude
MMI	Modified Mercalli Intensity
M_o	Lower magnitude of integration. Earthquakes with magnitude lower than M_o are not considered to be contributing to the seismic hazard
NC	North Central; Region 3
NE	North East; Region 1
NRC	Nuclear Regulatory Commission
PGA	Peak ground acceleration
PGV	Peak ground velocity
PRD	Computer code to compute the probability distribution of epicentral distances to the site
PSRV	Pseudo relative velocity spectrum. Also see definition of spectra below

Q Seismic quality factor, which is inversely proportional to the inelastic damping factor.

Q1 Questionnaire 1 - Zonation (I)

Q2 Questionnaire 2 - Seismicity (I)

Q3 Questionnaire 3 - Regional Self Weights (I)

Q4 Questionnaire 4 - Ground Motion Models (I)

Q5 Questionnaire 5 - Feedback on seismicity and zonation (II)

Q6 Questionnaire 6 - Feedback on ground motion models (II)

Q7 Questionnaire 7 - Feedback on zonation (III)

Q8 Questionnaire 8 - Seismicity input documentation

Q9 Questionnaire 9 - Feedback on seismicity (III)

Q10 Questionnaire 10 - Feedback on ground motion models (III)

R Distance metric, generally either the epicentral distance from a recording site to the earthquake or the closest distance between the recording site and the ruptured fault for a particular earthquake.

Region 1 (NE): North East of the United States, includes New England and Eastern Canada

Region 2 (SE): South East United States

Region 3 (NC): North Central United States, includes the Northern Central portions of the United States and Central Canada

Region 4 (SC): Central United States, the Southern Central portions of the United States including Texas and Louisiana

RP Return period in years.

RV Random vibration. Abbreviation used for a class of ground motion models also called stochastic models.

S Site factor used in the regression analysis for G-Expert 5's GM model: S = 0 for deep soil, S = 1 for rock sites

SC South Central; Region 4

SE South East; Region 2

S-Expert One of the eleven experts who provide the zonations and seismicity models used in the analysis

SEP	Systematic Evaluation Program
SHC	Seismic Hazard Characterization
SHCUS	Seismic Hazard Characterization of the United States
SN	Site Number
Spectra	Specifically in this report: attenuation models for spectral ordinates were for 5% damping for the pseudo-relative velocity spectra in PSRV at five frequencies (25, 10, 5, 2.5, 1 Hz).
SSE	Safe Shutdown Earthquake
SSI	Soil-structure-interaction
SSMRP	Seismic Safety Margins Research Program
UB	Upper bound
UHS	Uniform hazard spectrum (or spectra)
USGS	United States Geological Survey
WUS	The regions in the Western United States where we have strong ground motion data recorded and analyzed

Overall Executive Summary

This study, for the Nuclear Regulatory Commission (NRC), constitutes the state of the art in terms of assessment of the seismic hazard for the locations of all active nuclear power plant sites in the northern American region east of the Rocky Mountains, which we refer to as Eastern United States (EUS).

Another similar study commissioned by the utility sponsored Electric Power Research Institute (EPRI) is in progress whose results will be available shortly.

Because of the importance of these two studies for the NRC, numerous reviews and comparisons have been performed by both groups of investigators, and generally it was found that the methodologies did not fundamentally differ in their principles, but if differences existed in the results, they had to be traced down to the various inputs used in the analyses. The results of this study, performed by Lawrence Livermore National Laboratory (LLNL), provide the NRC with the tools for characterizing the seismicity and ground motion in the EUS. These tools are:

a. A data base of zonation and seismicity models of the EUS for predicting the frequency of occurrence of earthquakes of any magnitude (or intensity) at any location in the EUS.

b. A data base of ground motion attenuation models for predicting the ground motion (in terms of peak ground acceleration (PGA) or the response spectral amplitudes with 5% of critical damping - (PSRV) at a site, when the size and location of the earthquake are known.

c. A seismic hazard model which, given the data bases in (a) and (b) above, provides an estimate of the probability of exceedance, at the sites, of any value of the ground motion (PGA and/or PSRV).

d. A data base of estimates of the seismic hazard at the 69 sites with either presently operating nuclear power plants or plants seeking a license.

Numerous studies, including several by NRC, have demonstrated the inherent uncertainty in estimating the seismic hazard in the EUS. Thus one important aspect of the methodology in this study was to attempt to capture this uncertainty, including both the random (physical) uncertainty and the modeling (knowledge) uncertainty. To this effect, expert opinion was used to develop the data bases described in (a) and (b) above. Two panels of experts were formed whose composition was carefully chosen to include experts with knowledge spanning the entire EUS, academics, utility consultants, and the United States Geological Survey (USGS), in the fields of geotectonics and seismicity features of the EUS and ground motion modeling.

The methodology and description of the data bases are given in a separate volume (Vol. I), and the results of the analysis are given in five other volumes for the 69 plant site locations. Of these 69 sites, 38 were with rock conditions, 14 were deep soil sites, and 17 were shallow soil sites. In addition, 12 of the rock sites also had areas with additional power plant units or other important buildings or constructions which were located on shallow soil.

Our methodology handles the various soil conditions by characterizing each one of them in either one of two ways:

(1) The soil site conditions are one of three: rock, deep soil or intermediate

(2) The soil site conditions are one of eight: rock, deep soil, shallow soil till-like (with three different depths) or shallow soil sand-like (with three different depth).

The uncertainty in the hazard is estimated by a Monte Carlo simulation. All the uncertain parameters (zonation, seismicity, ground motion models and site correction models) are simulated, and several percentiles in the hazard are calculated.

The results presented in this study consist of hazard curves at each site for PGA for the 15th, 50th and 85th percentiles, constant percentile hazard curves (CPHC), arithmetic mean (AMHC) and best estimate hazard curves (BEHC). Uniform hazard spectra for various return periods are also presented.

We compared the results of this analysis with one of our previous studies (Bernreuter et al., 1985) for 10 test sites. The differences between the two studies were minor "tuning" on the methodology and a complete review of the data bases, including a round of feedback with all the experts participating in the study. In spite of some changes in the opinions of several of the zonation and seismicity experts, the effects on the results were found to be minimal. On the other hand, the random vibration (RV) ground motion models which were not used in our previous studies because they had not been developed yet, took a 50% weight in the present study, as a result of opinion changes by the Ground Motion (GM) Expert Panel. The effect of these changes was primarily to change the average response spectral shape to allow for much higher spectral values at the higher frequencies (10 to 25 Hz) and relatively smaller values at lower frequencies (1 to 2 Hz).

The following is a set of general conclusions drawn from the entire study, for the most part described and summarized in Vol. VI of the report.

(1) There is substantial uncertainty in the estimate of the hazard. The typical range in the value of the probability of exceedance between the 15th and 85th percentile curves for the PGA is on the order of 40 times, for low PGA; it is more than 100 at high PGA values. This translates into an approximation factor of 4 in ground motion for the 15th-85th range of values in the PGA given a fixed return period, and similarly an approximate factor of 4 in the ground motion for the range of values in the PSRV for a given return period.

    The range between the 15th and the 85th percentile hazard curves represents the total uncertainty in estimating the seismic hazard at a site due to two sources of uncertainty:

- the uncertainty of each expert in the zonation, models and values of the parameters of the analyses

- the variation in the hazard estimates due to the diversity of opinions between experts.

The latter, or inter-expert variation, is an important contributor to the total uncertainty in the estimated hazard. Specifically, the magnitude of uncertainty introduced by the diversity of opinions between experts is of the same order, on the average, as the uncertainty in the hazard due to the uncertainty of an individual expert in the value of the parameters. However, at times the uncertainty between experts can be very large.

For a given acceleration value, the range of the median hazard values at all the sites analyzed falls within the 15th-85th percentile range of any one of those sites.

(2) The 50th percentile CPHC appears to be a stable estimator of the seismic hazard at the site. That is, it is the least sensitive to changes in the parameters, when compared to the other estimators considered in this study (arithmetic mean, best estimate, 15th or 85th percentiles).

(3) The process of estimating the seismic hazard in the EUS is reasonably stable. Comparison with our previous results indicated that there has not been a major shift in results over the past few years, although there have been some significant perturbations in the form of recent occurrences of EUS earthquakes and the completion of several major studies of the seismotectonics of the EUS. In the feedback performed in this study, there were some changes introduced by members of both the Seismicity and GM Panels. The computed hazard when aggregated over all experts did not significantly change. However, the introduction of the "new" random vibration models introduced a significant change in the spectral shape by raising the spectral values in the high frequency range and lowering it in the low frequency range.

(4) It is difficult to rank the uncertainties because zonation and the parameters of the recurrence models are hard to separate. Nevertheless, our results indicate that the uncertainty in zonation and ground motion models are more significant than the uncertainty associated with the seismicity parameters. The largest contribution to modeling uncertainty comes from the uncertainty of the ground motion. The correction for local site effects is a significant contribution to the overall uncertainty introduced by the ground motion models. However, as already noted, the uncertainty introduced by zonation and recurrence is also significant and of the same order of magnitude.

(5) Based on comparisons between the results of our broad generic study and site specific studies, we concluded in Bernreuter et al. (1985) that the scale of our study is adequate. No major differences in zonation or results occurred between our study and site specific studies.

(6) We found, consistent with the conclusions in Bernreuter et al. (1985), that generally earthquakes in the magnitude range 3.75 to 5 would significantly increase the estimated seismic hazard if they were included in the analysis. Thus, it may be important to keep in mind that the CPHCs and CPUHS presented in this study only include the contribution from earthquakes with magnitudes of 5 and greater when assessing the seismic safety of brittle components of nuclear power plant systems, e.g., such as relays. In addition, it must be kept in mind that the PGA value is not a good estimator of the loading that very stiff components will experience in the EUS. The actual ground motion will be amplified.

(7) We found that the correction for the site's soil category had an important effect on the estimated hazard. We concluded that the approximate correction to be applied to the estimated hazard for rock site to estimate the hazard for shallow soil conditions at the same site (the correction is done by multiplying each PGA value on the rock curve, for a given probability by a constant correction factor) would lead to an estimate of the hazard of the soil site within less than 13% of its actual value had we calculated the hazard for the soil site by our methodology. However, we found that for some sites, multiplying the median hazard curve for rock by the median correction factor would have given approximately the same median hazard curve we obtained by performing the full analysis with our probabilistic correction factors. Unfortunately, at the present time, we have not been able to develop criteria to identify when performing such operation is correct.

(8) Although the soil site correction is not region dependent, we found that other complex interactions, with zonation seismicity and ground motion models, made the site correction actually region dependent.

(9) We found that the input from some experts lead to either high or low estimates of the hazard at most sites. In particular G-Expert 5's input lead to results, in general, higher than when only the other 4 GM Experts' input is used.

We found that the impact from any S-Expert did not show a consistent deviation from the results of all the other S-Experts at all sites, however, the results from some of the S-Experts were found to be either high in some regions of the EUS (i.e., S-Expert 2) or low (i.e., Expert 12, especially in the South West and Central U.S.).

Finally, it is difficult to assess if our results have either a conservative or unconservative bias. We insisted that our panel members not introduce such biases in their inputs and we spent considerable effort in developing a methodology which would allow the experts to properly express their uncertainty without having to introduce some conservative approximations. This was particularly true in the area of regional ground motion modeling and in the incorporation of multiple alternatives to account for any local site amplification of the ground motion.

Executive Summary: Volume I

This Volume is the first of eight volumes. It provides an overview of the methodology that we developed as part of the project to incorporate the judgement of experts and their quantification of the uncertainties about their input into a seismic hazard analysis using a simulation approach. Our methodology relies heavily on our previous work, Bernreuter et al. (1985), and it highlights the improvements made in the final version of our methodology and computer codes.

In Section 2 and Appendix C we provide the basis for the seismic hazard analysis computer programs we developed to account for the uncertainty in the estimation of the seismic hazard at all EUS nuclear power plant sites using input from experts. This software incorporates a simulation approach to provide the experts with a relatively simple but effective way to express their uncertainty. The hazard methodology is based on a probabilistic model of the occurrence and distribution of magnitudes of earthquakes and the attenuation of the ground motion from a source to a site. It also includes modeling of local site effects.

In Section 3 we describe our elicitation process which was developed to give each expert sufficient flexibility to define his best estimate for the various parameters of interest, e.g., zonation, and to fully express his uncertainty. As part of our elicitation process, we assembled two groups of experts. One group, called our Seismicity Panel (S-Panel), is composed of experts in the seismic zonation of the EUS. The other group is composed of experts in ground motion estimation and we referred to them as our Ground Motion Panel (G-Panel). Our elicitation process also included a number of feedback loops to provide the experts with an understanding of the implications that their assumptions and models have on the computed hazards and to provide them with a simple formal way to update or change their input. In Section 3 and Appendix B we provide a summary of the final makeup of our panels and their input as it was used in our analysis.

Relative to the input data documented in our previous report, Bernreuter et al. (1985), the Ground Motion Experts extensively revised their input. Of the eleven S-Experts, three of them proposed totally new seismicity models, four of them retained their original model and the rest made minor changes.

In Section 4 a special effort is made to highlight the differences in results between our previous study, Bernreuter et al. (1985), and the present study. The important conclusion is, again, the stability of the seismicity modeling. We compared the new seismicity models with the previous ones by calculating the seismic hazard at the same ten sites and using the same ground motion models. The differences were quite small after combining over all the experts in spite of the fact that the results for some S-Experts changed significantly.

The final spectral ground motion models are significantly different from the previous (1985) set of models. This is due primarily to the fact that a new type of models have made its appearance, namely the random vibration, stochastic models.

Another important difference between the results of this analysis and the previous one, Bernreuter et al., (1985), is in the value of the minimum magnitude of the earthquakes contributing to the hazard which is magnitude 5 in the present study as opposed to 3.75 previously. The effect of this change is documented in the following Volumes II to V, by providing the best estimate seismic hazard created by the earthquakes of magnitude between 3.75 and 5.

Volume I contains in Appendix A the responses of the experts to the questionnaire on documentation. Appendix B provides all the final input data for the analysis, and Appendix C gives a detailed account of the methodology used in the analysis.

SECTION 1: INTRODUCTION

The impetus for this study was in a large part the result of the NRC's discussions with the U.S. Geological Survey (USGS) regarding the USGS's proposed clarification of their past position with respect to the 1886 Charleston earthquake. The USGS clarification was issued on November 18, 1982, in a letter to the NRC, which states that:

> "Because the geologic and tectonic features of the Charleston region are similar to those in other regions of the eastern seaboard, we conclude that although there is no recent or historical evidence that other regions have experienced strong earthquakes, the historical record is not, of itself, sufficient ground for ruling out the occurrence in these other regions of strong seismic ground motions similar to those experienced near Charleston in 1886. Although the probability of strong ground motion due to an earthquake in any given year at a particular location in the eastern seaboard may be very low, deterministic and probabilistic evaluations of the seismic hazard should be made for individual sites in the eastern seaboard to establish the seismic engineering parameters for critical facilities."

In response to this letter the NRC started several projects, one of which is this study, to assist them in assessing the implications of the USGS position.

The objectives of this study are:

1. To develop a seismic hazard characterization methodology for the entire region of the United States east of the Rocky Mountains (referred to as the EUS in this report).

2. To apply the methodology to all nuclear power plant sites East of the Rocky Mountains to assist the NRC staff in their assessment of the implications in the clarification of the USGS position on the Charleston earthquake, and the implications of the occurrence of other recent eastern U.S. earthquakes.

In this study we developed a methodology which allows experts to express their uncertainty about the seismotectonics of the EUS and to incorporate the experts' uncertainty into our analysis. We also provide a representative sample of expert judgment about the seismotectonic parameters that influence the estimates of the seismic hazard, in the form of strong shaking induced by future earthquakes, at any particular sites.

The methodology that we developed as part of this study has been discussed in detail in Bernreuter et. al. (1984,1985). However, for completeness and ease of reference in Section 2 of this report we provide an overview of our approach. In Appendix C, we also provide details of our methodology needed for an in depth understanding our our approach and results. In Section 3 we review how the inputs needed for the analysis were obtained. The inputs used in the analysis are given in the Appendix B of this report. In Section 4 we compare our updated results to our previous results given in Bernreuter et al. (1985).

Because of the large number of sites for which results are presented we have broken them up into four batches of roughly the same number of sites. The results for each region are presented in separate volumes- Volumes II-V. Table 1.1 lists the sites contained in each volume and Figs. 1a,b,c, and d give the location of each site. In selecting the sites for each batch an attempt was made to make a logical regional grouping of approximately the same size. Some compromises had to be made, particularly in batch 4. It can be seen from Figs. 1a and b that the sites in batch 1 correspond to the Northeast and batch 2 to the Southeast. Batch 3, as can be seen from Fig. 1.1c, covers the central part of the North Central region and Batch 4, as noted, is a potpourri of the remaining sites as can be seen from Fig. 1.1.d. There is a summary volume (Vol VI) which compares the results from the four regions and contains our overall conclusions and recommendations. Finally, in Vol. VII we provide all of our Questionnaires. To make it easier for the reader interested in only the results for a few sites, we have made volumes II-V independent of each other. Thus the reader only needs volume I which, as outlined above, gives the details of our methodology and inputs used in the analysis; the volume which has the results for the site of interest; and Volume VI which draws general conclusions and provides added sensitivity discussion. Needless to say in the lay out here is some considerable repetition of information in volumes I-V.

We started work developing our methodology in 1982. We completed our initial development of the inputs in 1983 and published our preliminary results in Bernreuter et al. (1984). After extensive peer review we made improvements to our methodology. We held extensive feedback sessions with our experts to update their input. We published our updated results in Bernreuter et al. (1985). The Electric Power Research Institute (EPRI) started a similar program in 1983 and provided their preliminary results in EPRI 1985. NRC funded us to perform an in depth comparison between our methodology and results at the nine sites and EPRI's methodology and results. The results of the comparison were published in Bernreuter et. al (1987) and are discussed in Section 4 of this report.

Because of the somewhat long time delay between our last update, completed in 1984 and because many of our experts were also members of the six EPRI Teams we undertook a final round of feedback to update the experts opinions.

The results presented in this report are based on the updated responses by our panel members from both the Seismicity and Ground Motion Panels. In this sense they are final results. However, as judgment plays a very significant role in developing the input data, it is likely, considering the large uncertainties expressed by each our our experts, that in the future various experts will modify their views thus leading to results which may differ from those presented here.

TABLE 1.1

List of Sites in Each Volume of this Report

Batch 1 - Sites in Vol.II
Plotted in Fig. 1.1a

Plot Symbol	Site
1	Fitzpatrick
2	Ginna-1
3	Haddam Neck
4	Hope Creek
5	Indian Point
6	Limerick
7	Maine Yankee
8	Millstone
9	Nine Mile Pt.
A	Oyster Creek
B	Peach Bottom
C	Pilgrim
D	Salem
E	Seabrook
F	Shoreham
G	Susquehanna
H	Three Mile Island
I	Vermont Yankee
J	Yankee at Rowe

Batch 2 -Sites in Vol. III
Plotted in Fig. 1.1.b

Plot Symbol	Site
1	Bellefonte
2	Browns Ferry
3	Brunswick
4	Calvert Cliffs
5	Catawba
6	Farley
7	Hatch
8	McGuire
9	North Anna
A	Oconee
B	Robinson
C	Sequoyah
D	Shearon Harris
E	Summer
F	Surry
G	Vogtle
H	Watts Bar

Batch 3 - Sites in Vol. IV
Plotted in Fig. 1.1.c

Plot Symbol	Site
1	Beaver Valley
2	Big Rock Point
3	Braidwood
4	Byron
5	Clinton
6	Cook
7	Davis Besse
8	Dresden
9	Fermi
A	Kewaunee
B	LaSalle
C	Palisades
D	Perry
E	Point Beach
F	Quad Cities
G	Zion

Batch 4 - Sites in Vol.V
Plotted in Fig. 1.1d

Plot Symbol	Site
1	Arkansas
2	Callaway
3	Comanche Peak
4	Cooper
5	Crystal River
6	Duane Arnold
7	Fort Calhoun
8	Grand Gulf
9	LaCrosse
A	Monticello
B	Prairie Island
C	River Bend
D	South Texas
E	St. Lucie
F	Turkey Point
G	Waterford
H	Wolf Creek

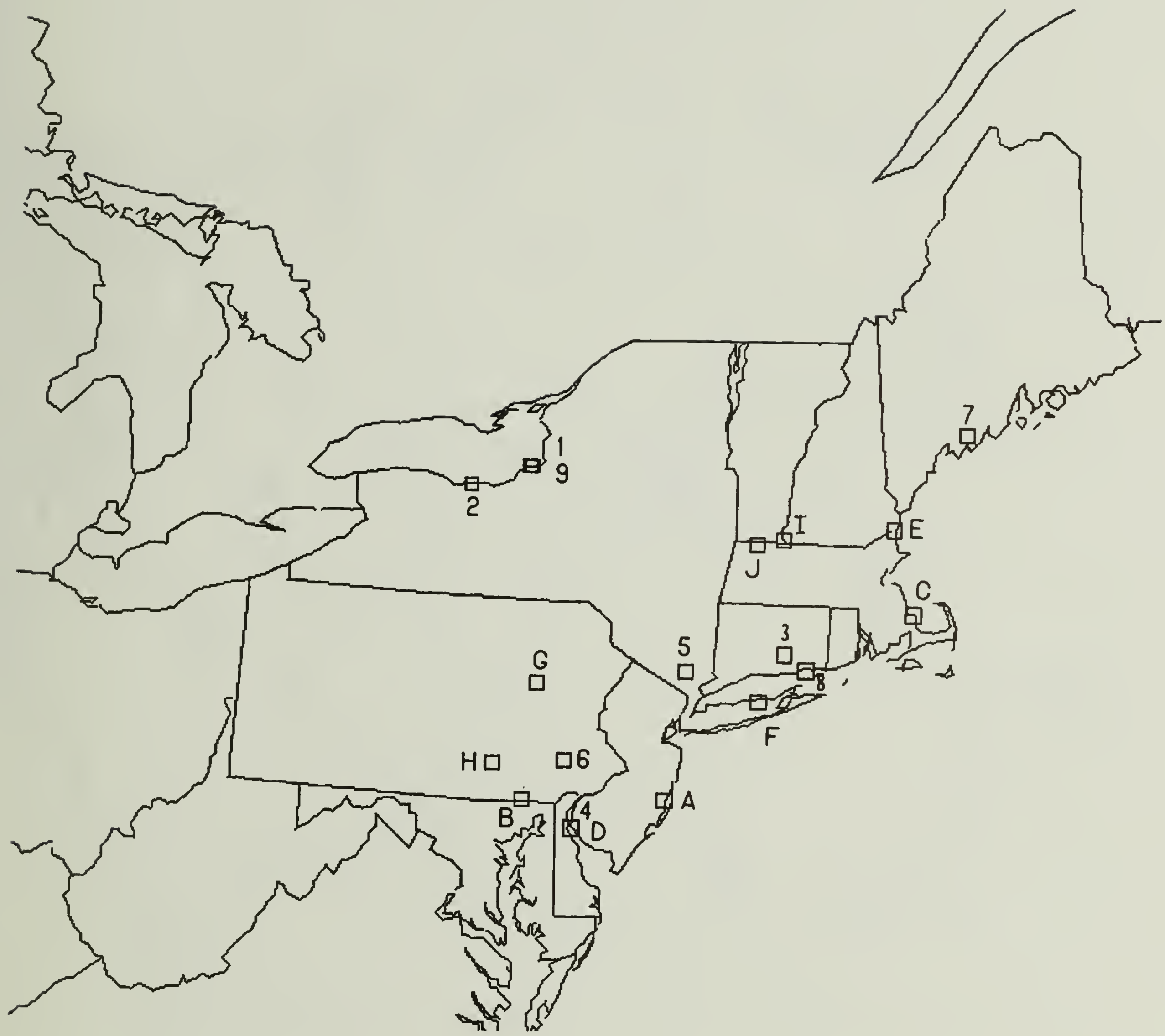


Figure 1.1a Map showing the location of the Batch 1 sites contained in Vol. II of this report. Map symbols are given in Table 1.1.

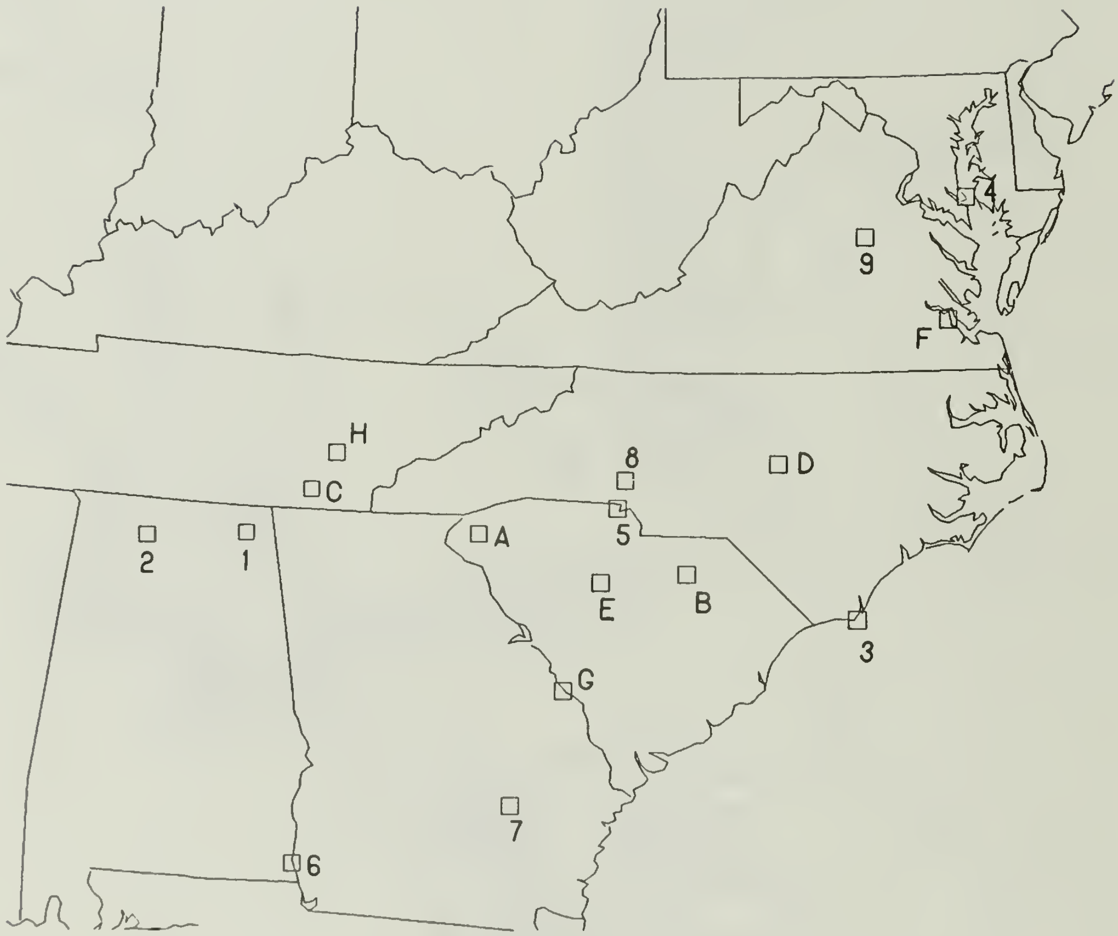


Figure 1.1b Map showing the location of the Batch 2 sites contained in Vol. III of this report. Map symbols are given in Table 1.1.

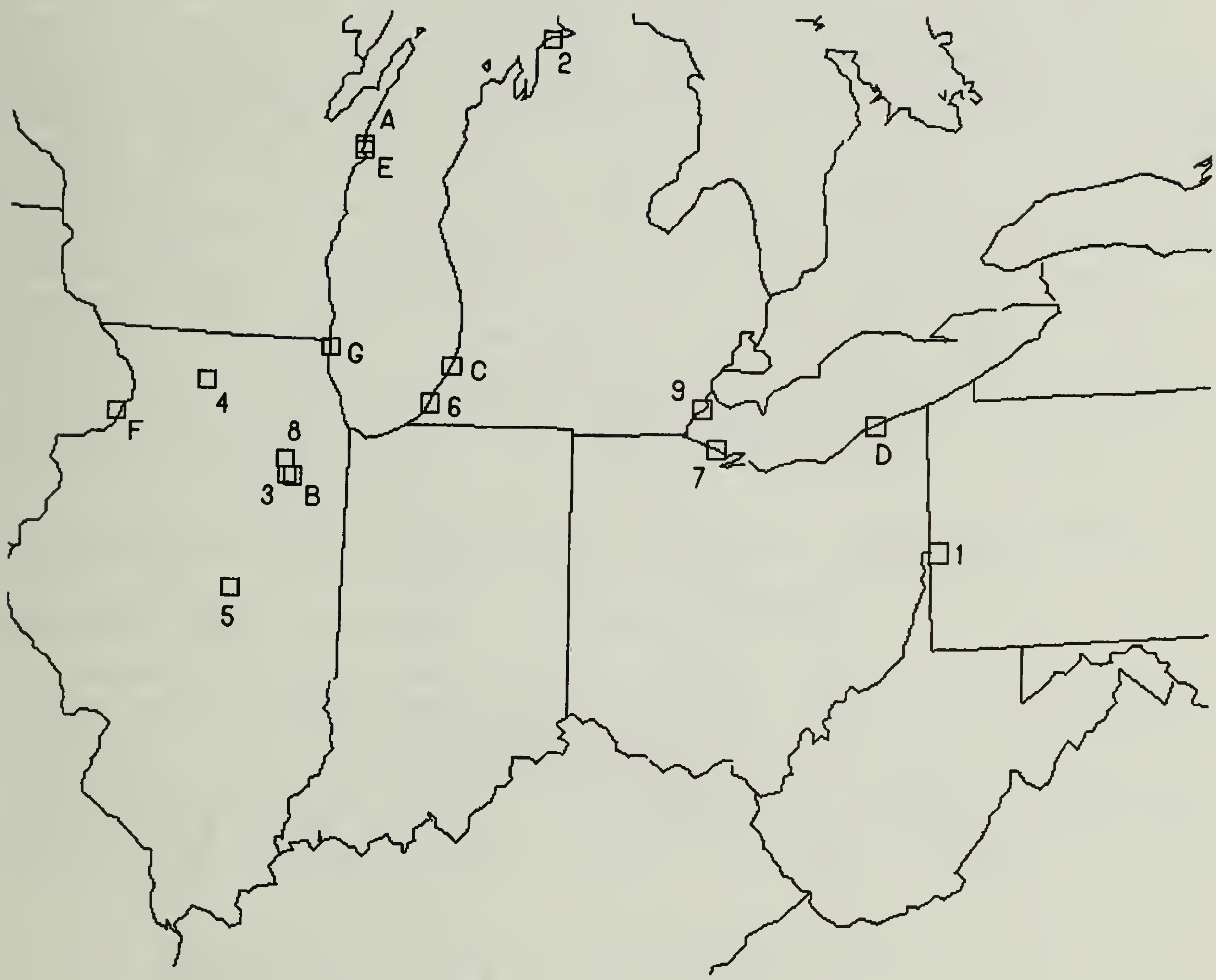


Figure 1.1c Map showing the location of the Batch 3 sites contained in Vol. IV of this report. Map symbols are given in Table 1.1.

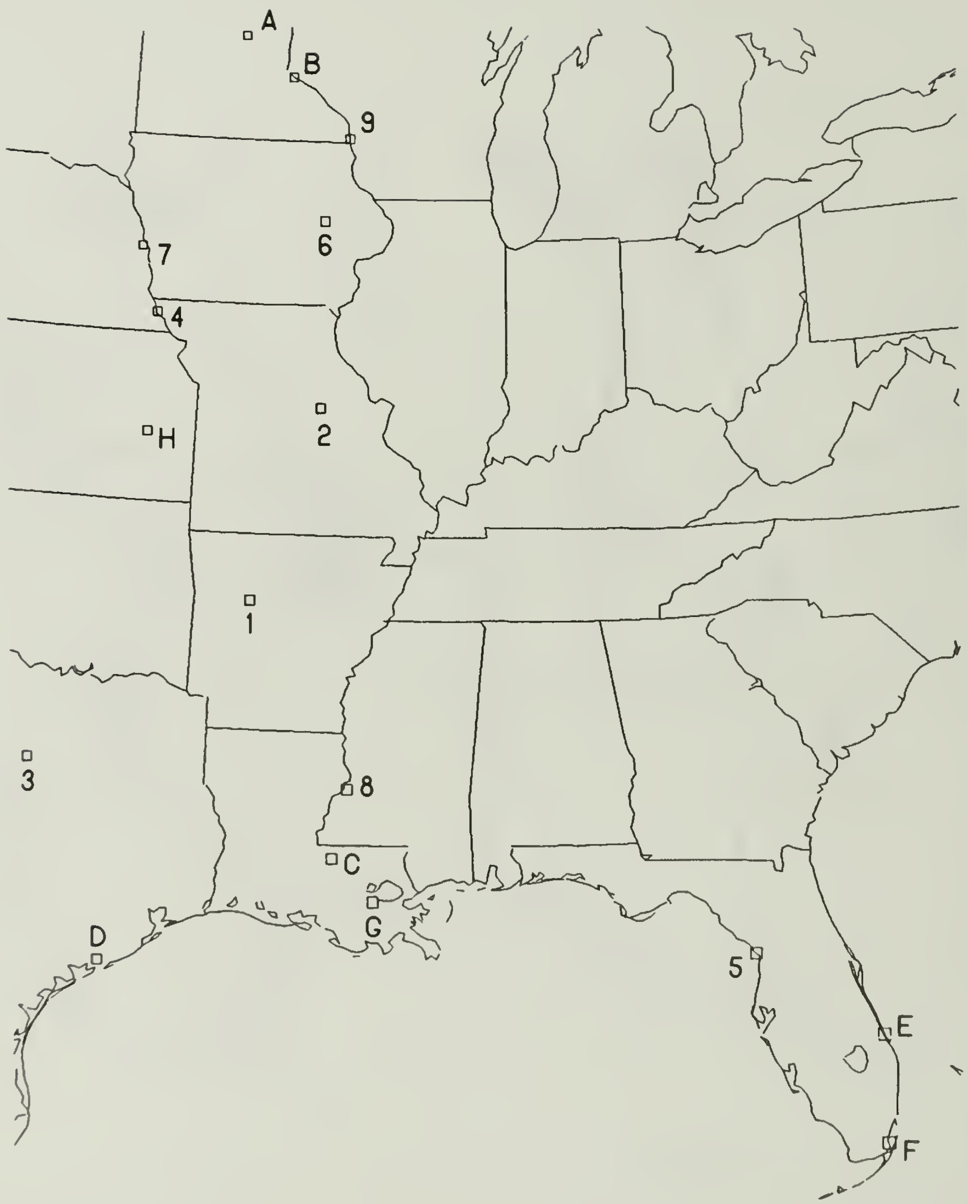


Figure 1.1d Map showing the location of the Batch 4 sites contained in Vol. V of this report. Map symbols are given in Table 1.1.

SECTION 2: OVERVIEW OF THE METHODOLOGY USED

2.1 Introduction

Seismic hazard analysis has been limited by the poor quality and sparsity of the available seismicity and strong motion data, particularly in the Eastern United States (EUS). As noted in Section 1, the purpose of this study was to develop a methodology and a data base so that the seismic hazard could be estimated at any site in the EUS. Our methodology is the outgrowth of previous studies, in particular, the Systematic Evaluation Program (SEP) study, Bernreuter and Minichino (1983) and the Seismic Safety Margins Research Program, Bernreuter et al. (1983) In the SEP study, we proposed the use of experts' opinions to supplement the sparse data. The results of the SEP study were point estimates of the seismic hazard. In this new study, referred to as The Seismic Hazard Characterization (SHC) project (Bernreuter et al. (1984, 1985) in this report, we incorporated several significant modifications to the SEP methodology. An important extension was recognition and inclusion of uncertainties in the analysis and its inputs. Thus, the results of the SHC include an estimate of the hazard with uncertainty bounds. Other methodologies now exist to perform the same tasks. In particular the EPRI study, EPRI (1985, 1986), sponsored by the utility companies, is similar in many respects to the SHC study. It, like SHC, combines experts' opinions with historical data and includes uncertainties in the analysis.

This section describes the SHC study in some detail. Emphasis is placed on eliciting the experts' opinions and the treatment of uncertainty.

2.2 Description of the Hazard Calculation Methodology

In the SHC study, the seismic hazard at a site is quantified by a seismic hazard curve which describes the relation between the value of a ground motion parameter, e.g., peak ground acceleration (PGA) and the probability it is exceeded in one year. The methodology is similar, in many ways, to the well-established methods developed by Cornell (1968), McGuire (1976), Algermissen et al.(1982), Mortgat and Shah, (1979) and Der Kiureghian and Ang (1977). All these studies involved four basic elements as described in Fig. 2.1:

- o Identification of seismic source zones (Fig. 2.1a).
- o A model describing the expected frequency as a function of magnitude (Fig. 2.1b).
- o A model describing the expected value of a ground motion parameter (e.g.., peak acceleration) as a function of the magnitude and distance to the source (Fig. 2.1c).
- o Integration into a seismic hazard curve (Fig. 2.1d).

In the SHC, the ground motion parameters considered are the peak ground acceleration (PGA) and the pseudo-relative velocity (PSV) of a 5% damping response spectrum . We assume that the region affecting the ground motion at the site can be partitioned into distinct areas of constant seismic

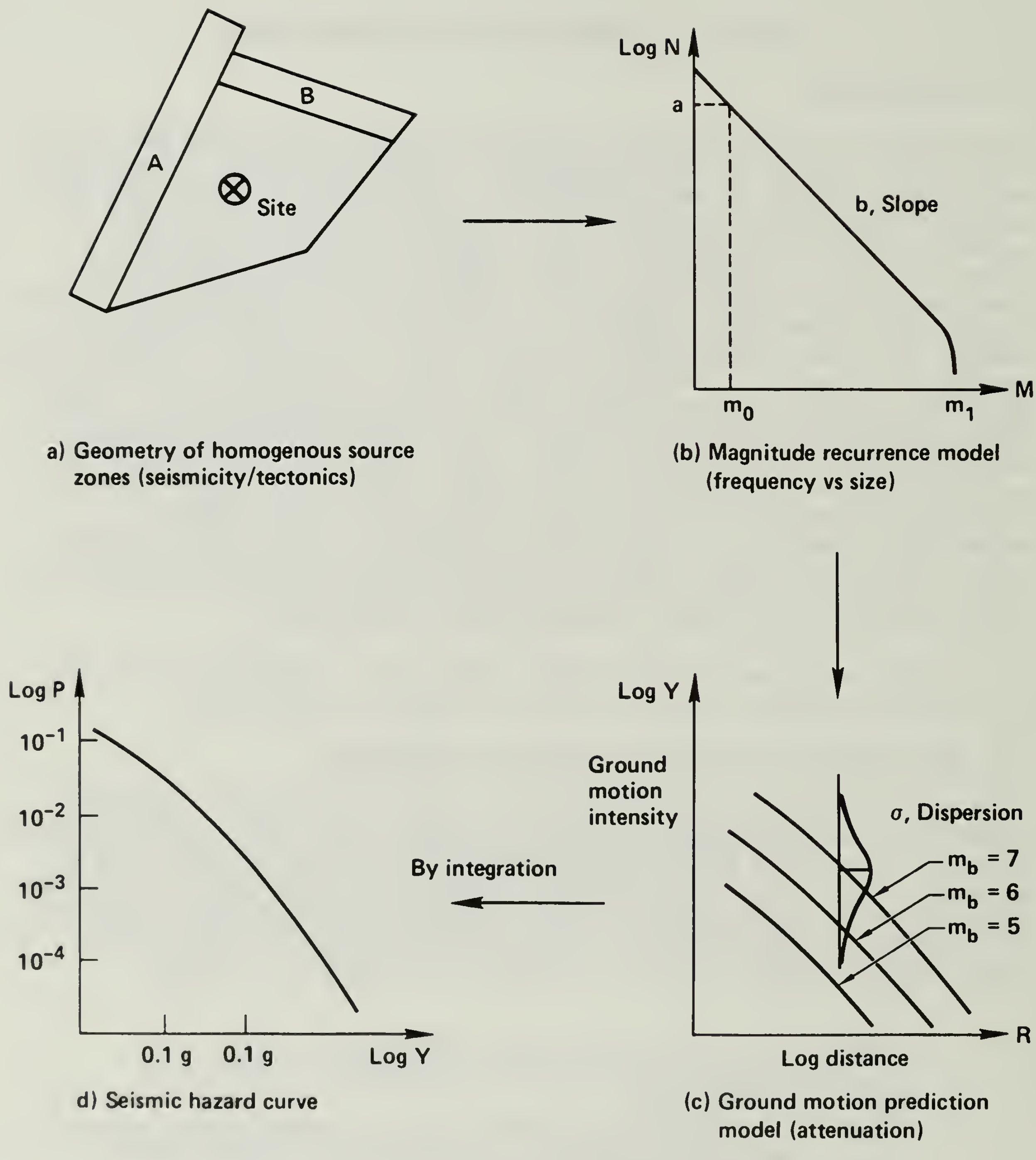


Figure 2.1 Four steps involved in a probabilistic seismic hazard analysis.

characteristics (referred to as source zones). This partition is partly based on geophysical information accumulated by each expert (such as tectonic stresses, plate motions, geology) and partly on observed seismicity developed by the individual expert's analysis of earthquake catalogs.

The following assumptions about the occurrence of earthquakes throughout the EUS form the basis for the probability calculations.

- o Earthquakes occur randomly over time and space within a source zone.
- o Earthquakes are point sources, thus the fact that they are created by rupture of tectonic faults is neglected.
- o The occurrence of earthquakes is independent between source zones.
- o The occurrence rate of earthquakes within a source zone is constant; its value describes the seismic and tectonic conditions that presently exist within the zone.
- o The expected number of earthquakes of magnitude m or greater, $\Lambda(m)$, per unit of area occurring within a zone is described by the magnitude recurrence relation

$$\log \Lambda(m) = H(m) \qquad M_0 \le m \le M_U \quad , \tag{2.1}$$

where M_0 is the minimum magnitude of interest and M_U (upper magnitude cutoff) is the maximum magnitude possible in the zone under the present tectonic conditions. M_U and the functional form H(m) are elicited from each of the experts.

Given these assumptions, the number $N_t(m)$ of earthquakes with magnitude greater than M, $m \ge M_0$, occurring within a zone in a time period of t years is a Poisson random variable with intensity parameter $\Lambda(m)$. Thus, the probability of exactly n earthquakes with magnitude greater or equal than m in t years is:

$$P\left[N_t(m) = n\right] = \frac{\left[t\Lambda(m)\right]^n}{n!} e^{-t\Lambda(m)} \quad ,n = 0,1,2,3,\cdots \tag{2.2}$$

Using the assumption that earthquakes are point sources which occur uniformly through a zone, if $N_t(r,m)$ is the number of earthquakes in t years of magnitude greater than m occurring at points which are a distance r to r+dr (kilometers) from the site, then $N_t(r,m)$ is a Poisson random variable with intensity parameter

$$\lambda_{m,t} = t\, \Lambda(m)\, f_R(r)\, dr \quad , \tag{2.3}$$

where $f_R(r)$ is the density function for the distribution of the distance from the site to points within a source zone.

Given an earthquake of magnitude M > m at a distance (r,r+dr) from the site, the ground motion parameter, e.g. ,PGA, at the site depends on the attenuation of the source energy between the source and the site. This is modeled as a random process. The expected value of PGA is described by a ground motion model depending on m and r. Since a multitude of such models exists, a panel of ground motion experts was used in the SHC project to select appropriate models. The conditional probability of PGA exceeding the value a, given m,r, is denoted $P(A>a|m,r)$, where A represents the peak ground acceleration.

Let $N_t(a)$ be the random variable, the number of earthquakes occurring in a zone in t years such that the PGA at the site is greater than a. The probability that one or more earthquakes occur in t years resulting in the PGA at the site exceeding a, denoted $P(A_t > a)$, is given by

$$P(A_t > a) = P(N_t(a) > 0). \tag{2.4}$$

Given the range of magnitudes (M_0, M_U), where M_U is the upper magnitude cutoff for the specific zone, and distances $r>0$, $N_t(a)$ is a Poisson random variable with intensity parameter $\lambda_a t$ where

$$\lambda_a = \int_{M_0}^{M_U} \int_{r>0} P(A>a|m,r)\, f_R(r)\, dr\, d\Lambda(m) \quad , \tag{2.5}$$

such that $d\Lambda(m) = \lambda_0\, dF_M(m|M_0,M_U)$ and λ_0 is the expected frequency, per unit time and area, of earthquakes with magnitude exceeding M_0, and $F_M(m|M_0,M_U)$ denotes the distribution function of magnitudes given an earthquake, conditional on minimum magnitude M_0 and upper magnitude cutoff M_U.

The probability that the maximum PGA at the site exceeds a, in a time period of length t, due to earthquakes occurring in zone q, is given by the complement to the probability of no such events, i.e., using the Poisson distribution,

$$\begin{aligned} P_q(A_t>a) &= P_q(N_t(a) > 0) \\ &= 1 - \exp(-\lambda_{aq} t) \quad , \end{aligned} \tag{2.6}$$

where λ_{aq}, given by Eq. (2.5) is the expected number of earthquakes per year causing a PGA greater than a at the site from earthquakes occurring in zone q. The distance density $f_R(\cdot)$ and magnitude distribution $F(\cdot|M_0,M_U)$ are dependent on the zone.

Finally, under the assumption that events between zones are independent, the seismic hazard in t years at a site caused by earthquakes occurring in all zones is given by:

$$P(A_t>a) = 1 - \prod_q [1-P_q(A_t>a)] = 1-\prod_q \exp(-\lambda_{aq} t). \tag{2.7}$$

In the SHC analysis, the ranges of magnitude and distance were discretized and Eq. (2.5) was approximated numerically by a series of summations. Several ground motion models and distributions were selected by the experts to model the conditional probability $P(A>a|m,r)$. Also the magnitude recurrence relationship, Eq. (2.1), was modeled by either a linear or bilinear truncated exponential relation, where the truncation was based on the model of Weichert, (1980) or a relationship developed in the SHC project.

2.3 Uncertainty in the Hazard

The limited historical data, empirical models, which lead to the uses of experts' opinions, caused the resulting hazard estimates to be uncertain. This uncertainty needs to be identified and included in the description of the seismic hazard. Thus, the hazard can be described not by a single curve, as in Fig. 2.1d, but typically by envelopes of percentiles of the hazard as shown in Fig. 2.2.

The approach developed for the SHC, is based on simulation to develop a probability distribution of the hazard. Using a Monte Carlo approach, each of the uncertain parameters is sampled a large number of times from its respective probability distribution describing the uncertainty in the parameter. With each hazard curve resulting from a given simulation is associated a weight, or probability of being the true hazard curve, which is calculated as the product of the probabilities or weights of each of the random parameter values used in that simulation. For each pair of seismicity and ground motion experts (respectively S- and G-Expert) described in Section 2.4, a typical simulation is as follows:

- o Draw a map from the distribution of maps for this S-Expert.
- o For each one of the seismic sources in a sample map, draw a set of seismicity parameters from their respective distribution, i.e.,:
  - a value for the a parameter of the recurrence law
  - a value for the b parameter of the recurrence law (b is allowed to have three levels of correlation with a, as specified by the S-Expert)
  - the value of the upper magnitude (or intensity) cutoff
- o Draw a ground motion model from the distribution of models.
- o Draw a value for the random uncertainty parameter, which is associated with the selected ground motion, for the appropriate EUS region (NE, SE, NC or SC).
- o Draw a site correction method.

The hazard is calculated for each of the seismic sources and combined for all sources. Each simulation gives a possible hazard curve. For each site typically 2750 such curves (50 simulations per G-expert times 5 G-experts times 11 S-Experts) were developed. Percentiles, usually the 15, 50 and 85th, are then used to describe the uncertainty in the hazard. This method, relative to discrete approaches such as, EPRI (1985, 1986) and YAEC (1973), provides more flexibility by allowing for a wider range of distributions to describe the uncertainties in the parameters. It also has the advantage of better sampling the tails of the distributions.

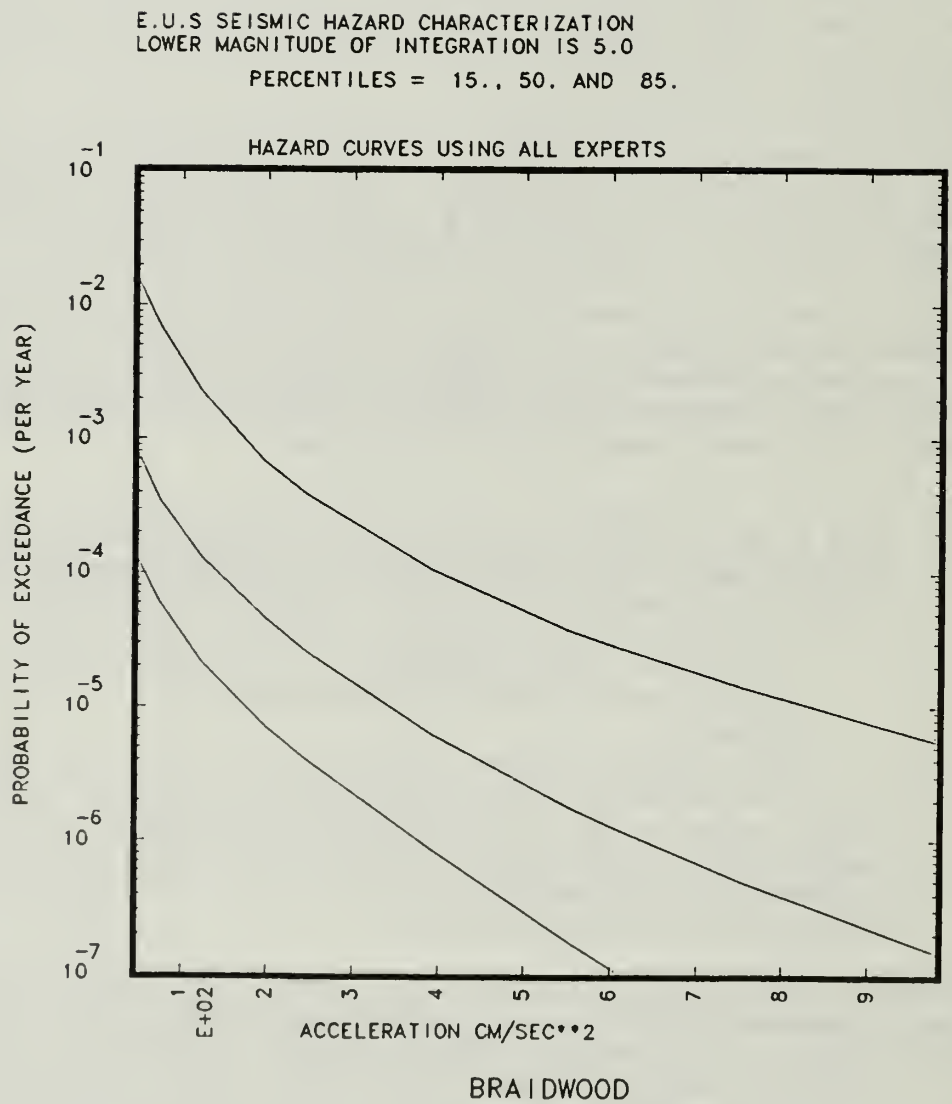


Figure 2.2 Typical results of our seismic hazard analysis. Shown are the 15th, 50th and 85th percentile PGA hazard curves for the Braidwood site.

2.4 Use of Experts' Opinion

The calculation of the hazard, described in Section 2.2, relies on the availability of data to develop the seismicity and ground motion models used in Eq. (2.5) i.e., the functions $f_R(r)$, $\Lambda(m)$ and $P(A>a|m,r)$. Only limited historical data are available for the EUS. Specifically, the earthquake catalogs cover only 200 to 300 years at the most, and must be used to make predictions in the range of 1000 to 10,000 years. Consequently, various interpretations are possible and the scientific community offers a diversity of opinion with respect to seismicity and ground motion prediction for the EUS. An important aspect of the SHC was to recognize this diversity which exists in the scientific community and to incorporate it in the uncertainty of the hazard. Thus, in the SHC the inputs, i.e., parameter values and models, for the hazard analysis were derived by eliciting experts' opinions in the fields of seismicity modeling and ground motion prediction modeling. To this end, two panels were formed. The S-panel was made up of experts on seismicity and zonation, and experts on ground motion prediction formed the G-Panel. As discussed in Section 3 the composition of the panels varied over the long course of this study. The individuality of the experts was emphasized by encouraging them to use their own information and data bases. The intent was to avoid the screening of non classical interpretations. Thus, we avoided favoring any kind of consensus among the experts including a consensus in the raw data or in the modeling. The methodology developed here was not intended to lead to some kind of artificial consensus, but rather the display of the full range of opinions was to be retained. The opinions of the experts were elicited through a series of written questionnaires, feedback meetings, and feedback questionnaires.

2.5 Aggregation of Experts' Opinions

When the opinions of several individuals are to be elicited, it is frequently necessary to consider ways of combining the information provided by the individuals into a single statement which represents, in some way, the "average" or consensus opinion of the group of individuals.

Basically, there are two classes of methods of aggregating experts' opinions. One class of methods is based on pooling some normalized quantification of the experts' opinions. In this case the experts are queried individually, are not expected to interact, and no attempt is made to reach a consensus through dialogue. Consensus is represented by the pooled quantification of opinions. The emphasis is placed on independence and free expression. The second class of methods attempts to reach a consensus. It is based on group interaction in which the experts are allowed to interact, with or without feedback, and through dialogue. In this case the free exchange of information is expected to result in a reduction in the range of views (Genset and Zidak (1984), Pill (1971) and Winkler(1968)), thus, seemingly, to imply a greater state of knowledge. However, unrestricted dialogue can be misleading since agreement may have been a result of strategic manipulation, intimidation, and other factors which could lead to biased results. To be effective the interaction must be well-planned and carefully directed.

The method used in the SHC is based on the former method, pooling of opinions. However, feedback, group interaction, extensive analysis of the responses, checks for consistency and gross errors, and a peer review were part of the overall elicitation process to alleviate some of the drawbacks associated with complete anonymity of the experts (e.g.., lack of responsibility, arbitrary answers).

Retention of the diversity of opinions between experts was an important consideration in the SHC project. Thus, individual hazard curves were estimated for each expert and the diversity of opinion between experts was included in the description of uncertainty.

In the case of the SHC the hazard is calculated for every pair of experts (i.e., S-Expert and G-expert) and these are subsequently combined. The combination rule is based on a normalized weighted average of the hazard curves or individual hazards in the uncertainty analysis. The weights for the G-experts were normalized values of self-weights the experts provided. The weights for the S-Experts were themselves a weighted average of four regional self-weights provided by the S-Experts, i.e.,

$$w_s = \sum_w w_{sw} \, P(A=A_w), \qquad (2.8)$$

where w_s is the single weight for the s-th expert, w_{sw} is the self-rating of the s-th expert for region w, and $P(A=A_w)$ is the probability that the maximum PGA at the site results from an earthquake originating in the w-th region. The four regions are indicated on Fig. 2.3. An appealing property of Eq. (2.8) is that it will provide a "high" value for w_s if the self-weight is highest in the region with highest probability of producing the maximum PGA. Conversely, it will be low if the weight is highest in the region with the lowest probability of producing the maximum PGA.

2.6 Hazard Analysis Outputs

Generally, the hazard at a site has been described in terms of a hazard curve, i.e., a graph of the probability that within a period of one year the maximum value of a ground motion parameter, e.g., peak ground acceleration or velocity, will exceed a given level, say A, as a function of a. A number of different estimators of the seismic hazard exist and are described in detail in Appendix C. One estimator produced by the SHC methodology is referred to as the best estimate hazard curve (BEHC). This is the hazard curve, for a particular pair of seismicity and ground motion experts, based on using the best estimate (BE) models and parameter values given by the experts. This corresponds to the hazard curve that would be produced if only a single source of seismicity and ground motion information were available and no uncertainty information were elicited. The BEHC is not necessarily the "best estimator", but is simply one possible estimator of the seismic hazard at a site. Figure 2.4 gives a typical set of BEHC for PGA at the Braidwood site. For the case shown, S-Expert 1 was used and the five BEHCs (one for each G-Expert) are plotted. It should be noted that G-Experts 3 and 4 both had the same BE PGA ground motion model hence their BEHCs are the same. See Appendix C for further discussion.

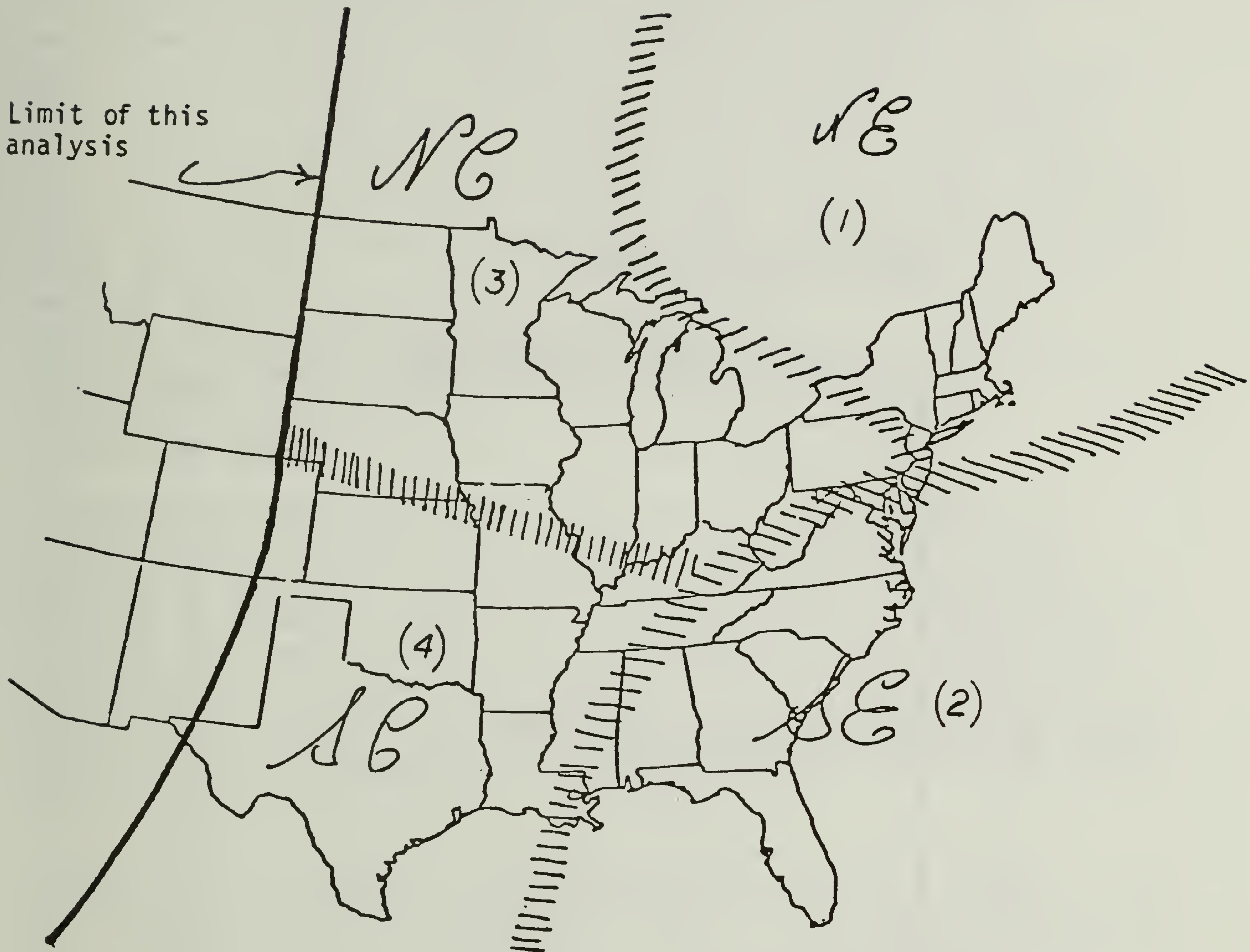


Figure 2.3 Map indicating the boundary of the four regions of the EUS used by our S-Experts to determine their self weights and by the G-Experts to select ground motion models.

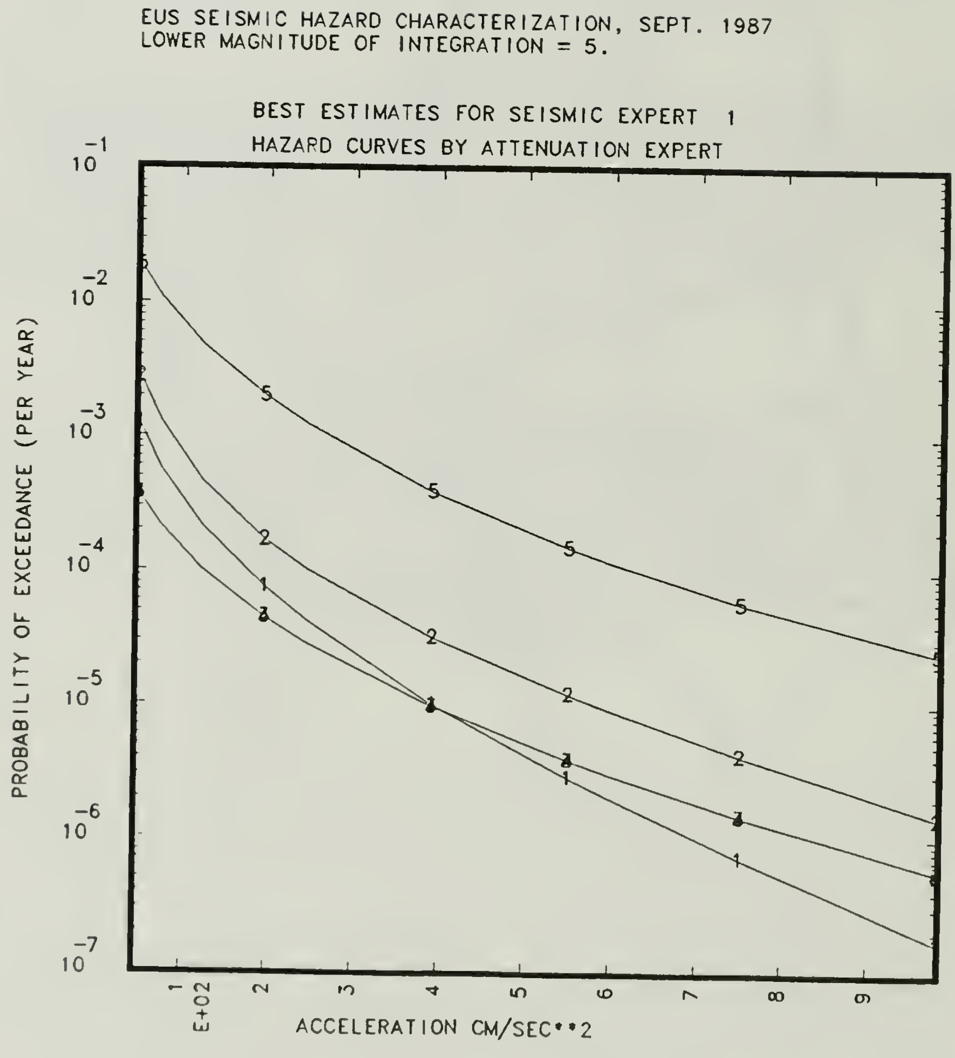


Figure 2.4 BEHC for PGA per G-Expert for S-Expert 1's zonation and seismicity parameters.

A second type of estimator produced by the SHC methodology, referred to as constant percentile hazard curve (CPHC), is based on using the uncertainty information provided by the experts. As explained in Appendix C, the percentiles derived here are the actual percentiles in the data sample obtained in the Monte Carlo simulation. It is not the percentiles one would obtain by fitting a probability distribution on these data. A probability (uncertainty) distribution for the hazard at each value, a, is developed by treating all the input models and parameters as uncertain variables and using simulation combining the percentiles of the hazard over all levels (over the range of a) gives a CPHC. The 15th, 50th and 85th CPHC's were most often used in the LLNL studies. Just as the BEHC, the CPHCs can be produced for each S-Expert and G-expert pair. Such curves describe the uncertainty expressed by a particular pair of experts. CPHCs for each S-G-Expert pair were not produced. CPHCs were produced for each S-Expert for all of the G-Experts. A typical set is plotted in Fig. 2.5 for S-Expert 1. Of most interest are the CPHCs obtained by aggregating over all S and G-Experts producing an uncertainty distribution for the hazard which describes both experts' uncertainties as well as diversity of opinions between experts.

In addition to generating a BEHC for each pair of S and G-experts, the methodology includes aggregations of curves. Such combinations of hazard curves were based on using the self-weights provided by the experts, as discussed in Section 2.5. One level of aggregation consists in combining the BEHC over ground motion experts for each seismicity expert. Figure 2.6 gives a typical set of BEHCs, one for each of the S-Experts at the Braidwood site. These aggregated curves can also be combined over seismicity experts to form a second level of aggregation. An additional aggregated estimator is considered in the LLNL methodology. It is the arithmetic weighted average of the hazards (AMHC). In Fig. 2.7 we compare the aggregated (over all S and G-Expert) BEHC and AMHC for the Braidwood site.

As was found in the analysis, the probability density function of the probability of exceedance of a given ground motion value is, in general, close to a lognormal probability distribution. Thus the arithmetic mean is expected to be in general closer to the 84th percentile, and much higher than the best estimate which is closer to the median (for a lognormal distribution, the median or 50th percentile is also the mean of the logarithms of the probability of exceedance).

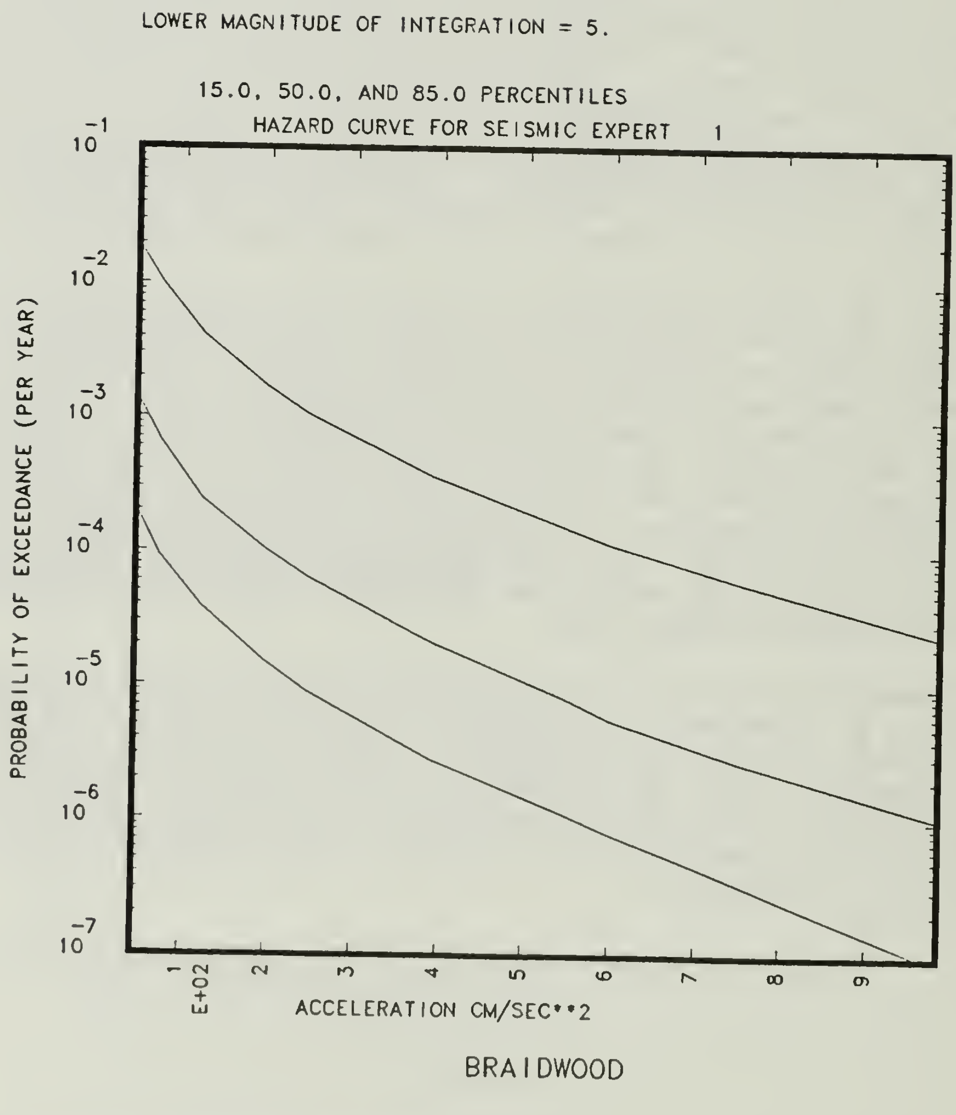


Figure 2.5 15th, 50th and 85th CPHC for PGA for S-Expert 1 aggregated over all G-Experts for the Braidwood site.

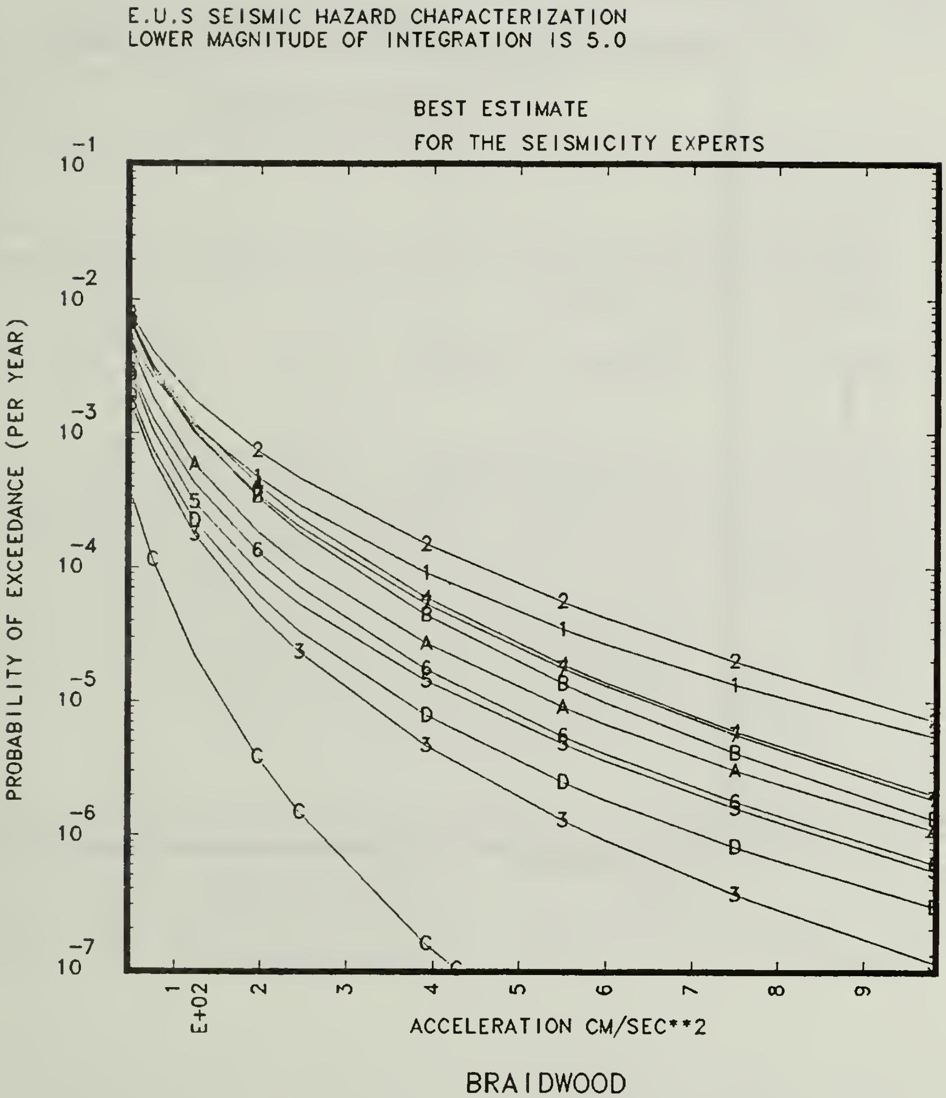


Figure 2.6 BEHC per S-Expert aggregated over all G-Experts for PGA for the Braidwood site.

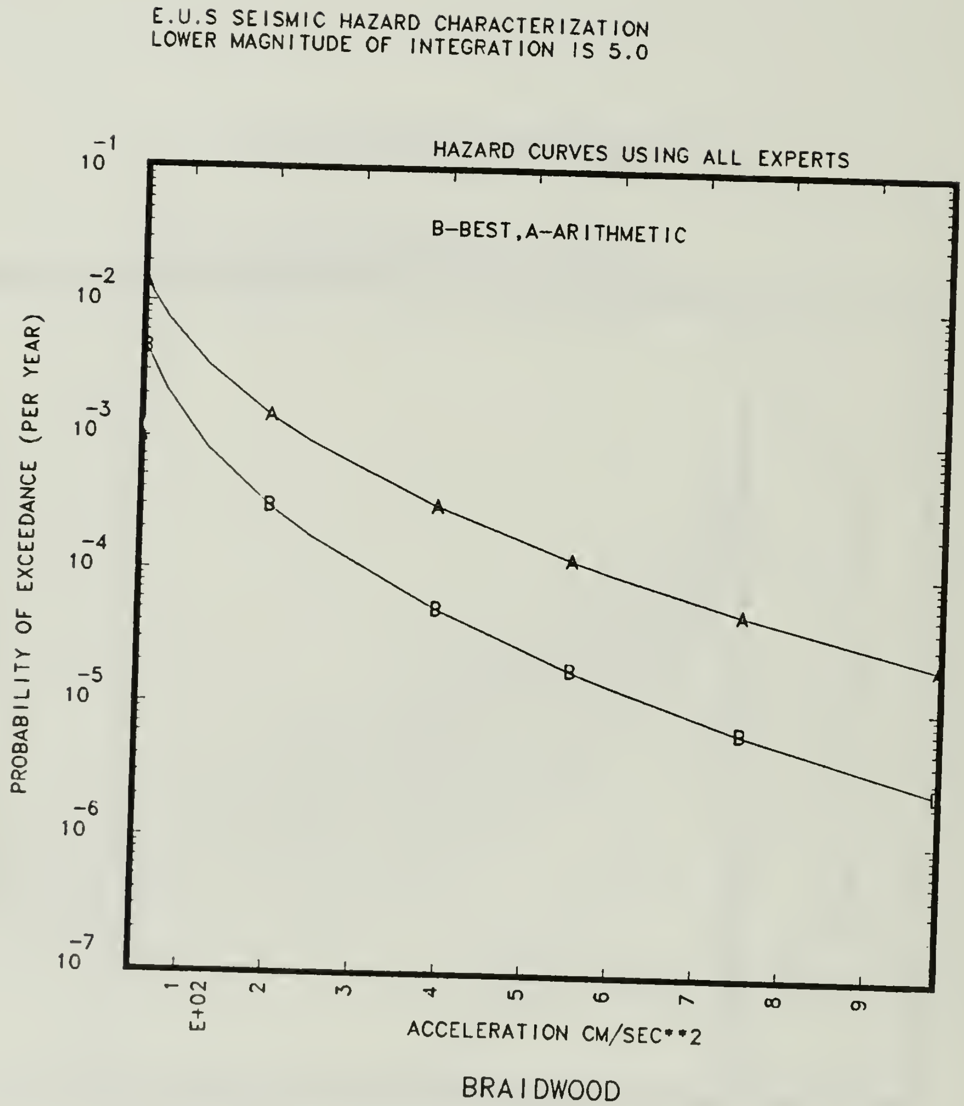


Figure 2.7 Comparison of the BEHC and AMHC for PGA aggregated over all S and G-Experts for the Braidwood site.

SECTION 3: DEVELOPMENT OF HAZARD ANALYSIS INPUTS

3.1 Processes Used for the Elicitation of Expert Opinion

There are a variety of ways in which expert opinion may be elicited (Mensing, (1981)). Our approach combines several different methods. It is characterized by the following key features:

- o Two panels of experts were formed. The S-panel provided input for the zonation and seismicity of the EUS and the G-panel provided input for the ground motion attenuation from EUS earthquakes. (see Tables 3.1 and 3.2)
- o Detailed questionnaires, requiring several days of effort by the panelist to complete, were distributed.
- o Panel members were generally paid.
- o Follow-up discussions and a feedback meetings were held for each panel.
- o The responses of each panel member were used in a separate hazard analysis and combined at the last step with other experts.
- o The elicitation process and hazard analysis methodology were subject to peer review.
- o Additional formal feedback loops were performed to finalize the input data.

In designing the elicitation process one of our guiding principles was to make sure that all experts had complete flexibility to develop their resources and opinions independent of the other panelists. We wanted everyone to function independently in formulating their opinions. Thus, we did not attempt to structure the experts line of thinking about the issues relevant to EUS seismicity. This allowed them the flexibility to use analytical methods as well as personal intuition and insight to the degree they felt appropriate. Overall, we wanted to assure that everyone could express their opinions without regard whether a consensus was being formulated among the participants. That is, we wanted everyone to feel free to express their opinions, even if they differed from the opinions of the other panelists. Thus, we wanted to be able to capture the range of opinions that might exist among knowledgeable individuals. We believe that our elicitation process has followed this principle. Our elicitation procedure was based on the experience gained during the SEP study and incorporates suggestions made by both the SEP Peer Review Panel, Bernreuter and Minichino (1983) and the SSMRP Panel on Subjective Inputs, Bernreuter et al. (1983) as well as other reviewers' comments.

Initially fourteen well known geoscientists knowledgeable about the seismicity and tectonics of the Eastern and Central U.S. formed one panel called the S-Panel (EUS Seismicity Panel), the list of whom is given in Table 3-1. Drs. Stevens and Wentworth subsequently resigned from the panel after providing us with their zonation maps. Dr. Basham resigned after providing his seismicity parameters, limited to Canada thus making his data incomplete for use in our analysis. However he participated in the zonation seismicity feedback meeting, providing many useful inputs and generating discussions on the seismicity of Canada and the North East of the United States with the other panel members. The remaining eleven experts provided input to develop the overall earthquake occurrence model.

The second panel, the G-Panel (the EUS Ground Motion Modeling Panel), initially included five members. Professor Nuttli left the G-panel in the summer of 1986, due to illness, he died in 1988. Drs. Dwyer and Anderson were added in Fall of 1986. Professor Toksoz attended our final workshops and contributed to the discussion, but because of other pressing commitments was unable to complete the final ground motion questionnaire, and thus was dropped from the final analysis as a G-Expert, but remained as one of the S-Experts. The list of members in the G-Panel (G-Experts) is given in Table 3-2.

We investigated the impact of this loss of continuity in the G-Panel make-up by comparing the results presented in our previous reports Bernreuter et al. (1984, 1985) and this report (see Section 4).

As can be seen in the flow chart of Table 3.3, considerable interaction, both formal and informal, took place between LLNL and the expert panel members. However, following our approach at no time during the elicitation were the experts forced or even encouraged to reach a consensus. As previously discussed, this study was designed as an expert opinion sampler. Thus initially we limited the amount of common information that we provided our S-Experts to a sorting of the earthquake per their zonation. Only at the second feedback level, Q9, did we provide them estimates of the a and b-values. The SHC is, as discussed in Bernreuter et al (1987) and Section 4, conceptually different from other current studies, such as the one sponsored by the EPRI, whose goals are to try and reach a consensus of opinion at some levels in the analysis.

Our goal in eliciting subjective judgment in the manner outlined in Table 3-3 was twofold. First, we believed it would give an accurate representation of the experts' views about parameters that affect seismic hazard. Second, it enabled us to retain the diversity of opinion which may exist in the scientific community. Ten questionnaires were designed and sent to the experts in order to collect all the necessary data for the analysis. They are the following:

Questionnaire 1 - Zonation Questionnaire (Q1)
Questionnaire 2 - Seismicity Questionnaire (Q2)
Questionnaire 3 - Questionnaire on Regional Self Weights (Q3)
Questionnaire 4 - Ground Motion Models Questionnaire (Q4)
Questionnaire 5 - Feedback-1 Questionnaire on Zonation/Seismicity (Q5)
Questionnaire 6 - Feedback-1 Questionnaire on Ground Motion Models (Q6)
Questionnaire 7 - Feedback-2 Zonation Questionnaire (Q7)
Questionnaire 8 - Documentation Questionnaire (Q8)
Questionnaire 9 - Feedback -2 Seismicity Questionnaire (Q9)
Questionnaire 10 - Feedback -2 Ground Motion Questionnaire (Q10)

Questionnaires Q1, Q2, Q3, Q5, Q7, Q8 and Q9 pertain to the S-Experts on zonation and seismicity. Q4, Q6 and Q10 pertain to the G-Experts. A copy of these questionnaires is given in the Vol. VII of this report, in the form as they were sent to the experts.

The original plan was to compute the seismic hazard at all EUS sites using the methodology and expert input data as it existed with the experts' responses to Q1-Q6. However, as the initial EPRI results were becoming available, it was deemed worthwhile to compare the results of the SHC and EPRI studies and to assess the meaning of the differences in estimates of the seismic hazard between the two studies at the test sites before continuing the analysis for all EUS sites. The results of this comparison are given in Bernreuter et al. (1987). Because of the somewhat long delay between the answering of Q1-Q6 by our experts and the starting of our final computations, new data and studies had become available particularly in the area of ground motion modeling. In addition many of our experts also participated in the EPRI study and attended the EPRI workshops on modeling the seismicity of the EUS and the ground motion modeling in the EUS. Thus NRC funded a second feedback round allowing experts to update their answers to the questionnaires.

In the following sections, we briefly describe the intent and highlights of the Questionnaires. In each case we desired not only an expert's opinion regarding the "most probable value" of a parameter but also, whenever possible, a measure of his uncertainty in determining the value of the parameter.

The experts of both the S and G Panels were instructed to avoid cognitive biases insofar as possible. For example, three points were emphasized:

- Answers were to be based on experience, geologic, tectonic and geophysical considerations, and all other available data.
- The level of confidence each expert placed in his answers would be explicitly considered. Therefore, since his input would undergo filtering and weighting when combined with the opinion of other experts, the expert was asked not to feel reluctant to express nonclassical viewpoints.
- The experts were urged to attempt answering all questions.

TABLE 3-1

EUS ZONATION AND SEISMICITY PANEL MEMBERS
(S-Panel)

Dr. Peter W. Basham(2)

* Professor Gilbert A. Bollinger(1)

* Mr. Richard J. Holt(1)

* Professor Arch C. Johnston

* Dr. Alan L. Kafka

* Professor James E. Lawson

* Professor L. Tim Long(5)

* Professor Otto W. Nuttli(1)&(4)

* Dr. Paul W. Pomeroy(1)

* Dr. J. Carl Stepp

Dr. Anne E. Stevens(3)

* Professor Ronald L. Street(1)

* Professor M. Nafi Toksöz (1)&(4)

Dr. Carl M. Wentworth(3)

Notes:
(1) Also participated in the SEP Panels
(2) Only provided zones and seismicity parameters for Canada
(3) Only provided zonation--no seismicity parameters
(4) Also member of the Ground Motion Panel (Table 3-2)
(*) Final member of the S-Panel

TABLE 3-2

EUS GROUND MOTION MODEL PANEL MEMBERS
(G-Panel)

* Dr. David M. Boore[1]

* Dr. Kenneth Campbell

Professor Otto W. Nuttli[1] [2] [3]

Professor Nafi Toksöz [2]

* Professor Mihailo Trifunac[1]

* Dr. John Anderson [4]

* Dr. John Dwyer [4]

Notes:

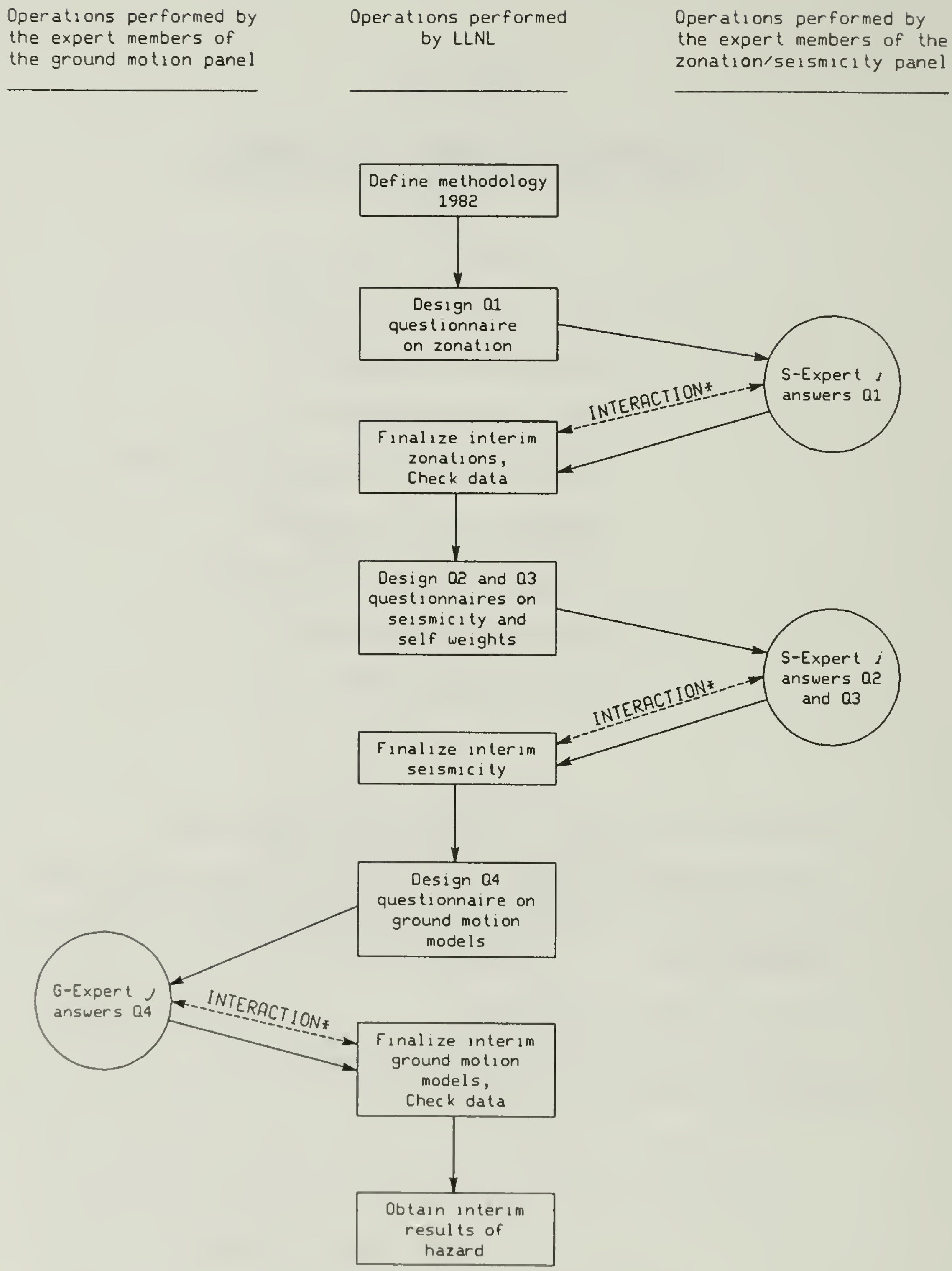
* Provided the final sets of ground motion models used

(1) Participated as a member of the SEP EUS Ground Motion Panel.

(2) Also member of the Seismicity Panel (See Table 3-1), did not complete Q10.

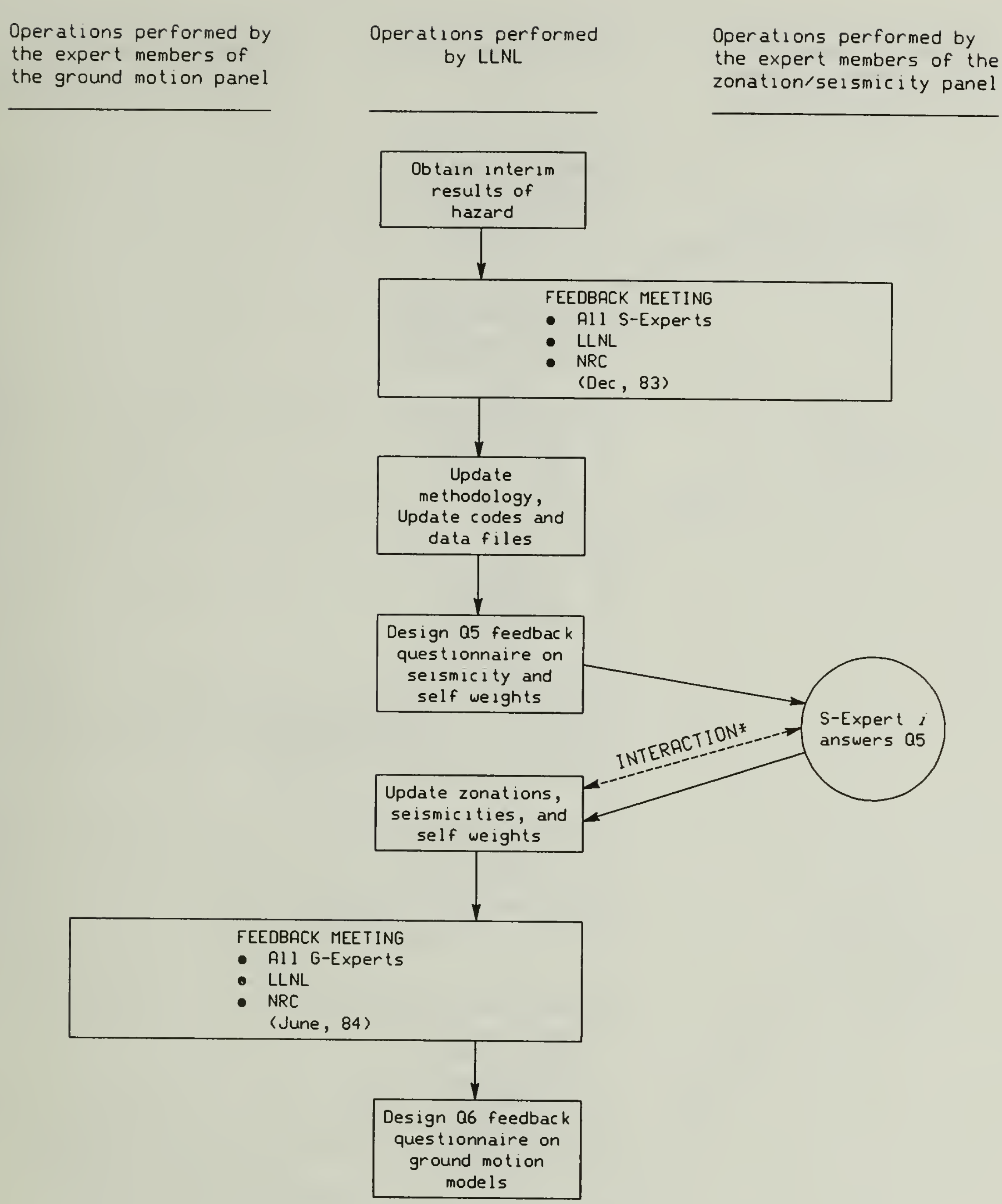
(3) Left the Panel in June 1986

(4) Added to the Panel in the Fall of 1986



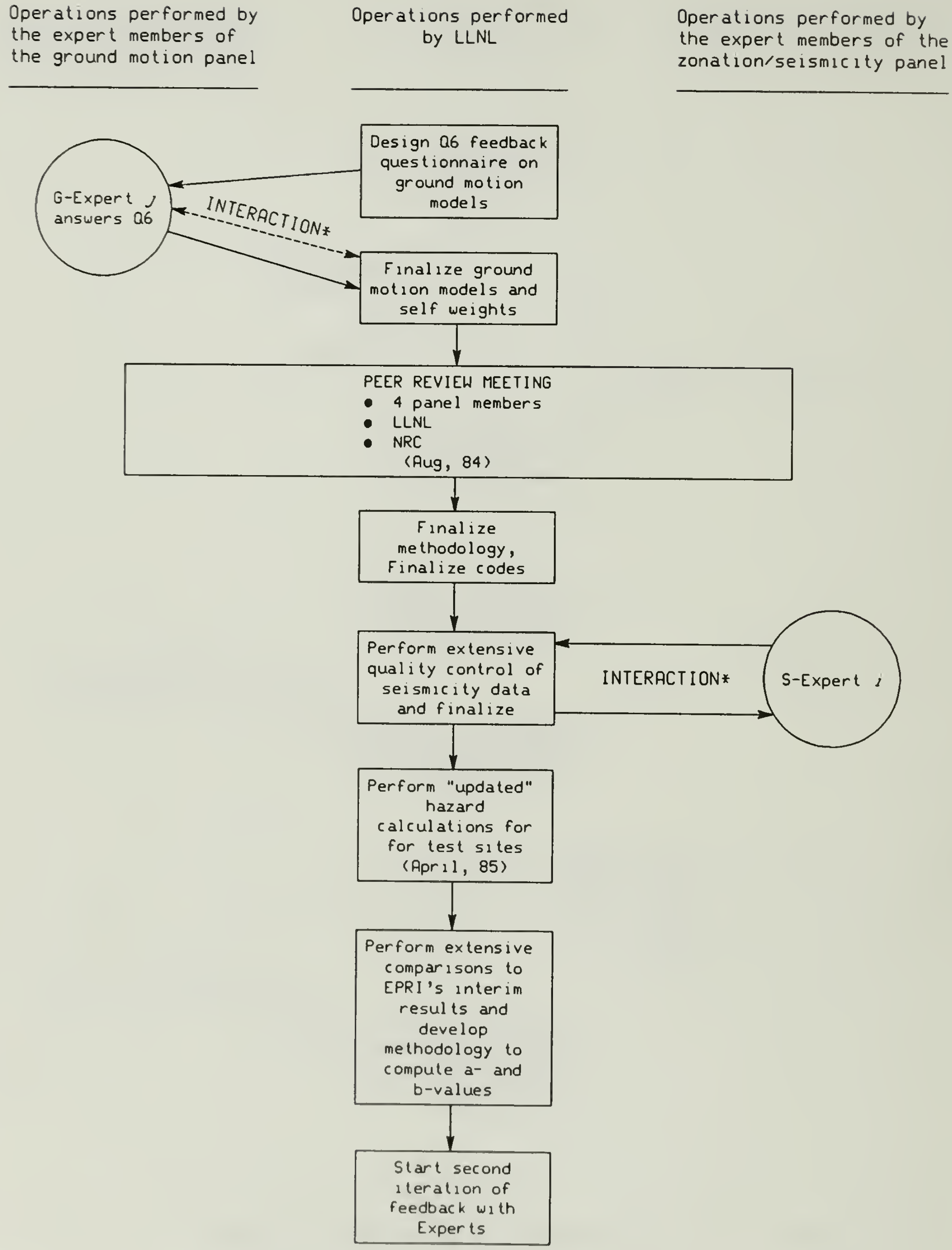
* Mostly by phone or mail, but also meeting in person for a few cases.

Table 3.3. Schematic representation of the flow of operations in the elicitation of the Experts' opinions.



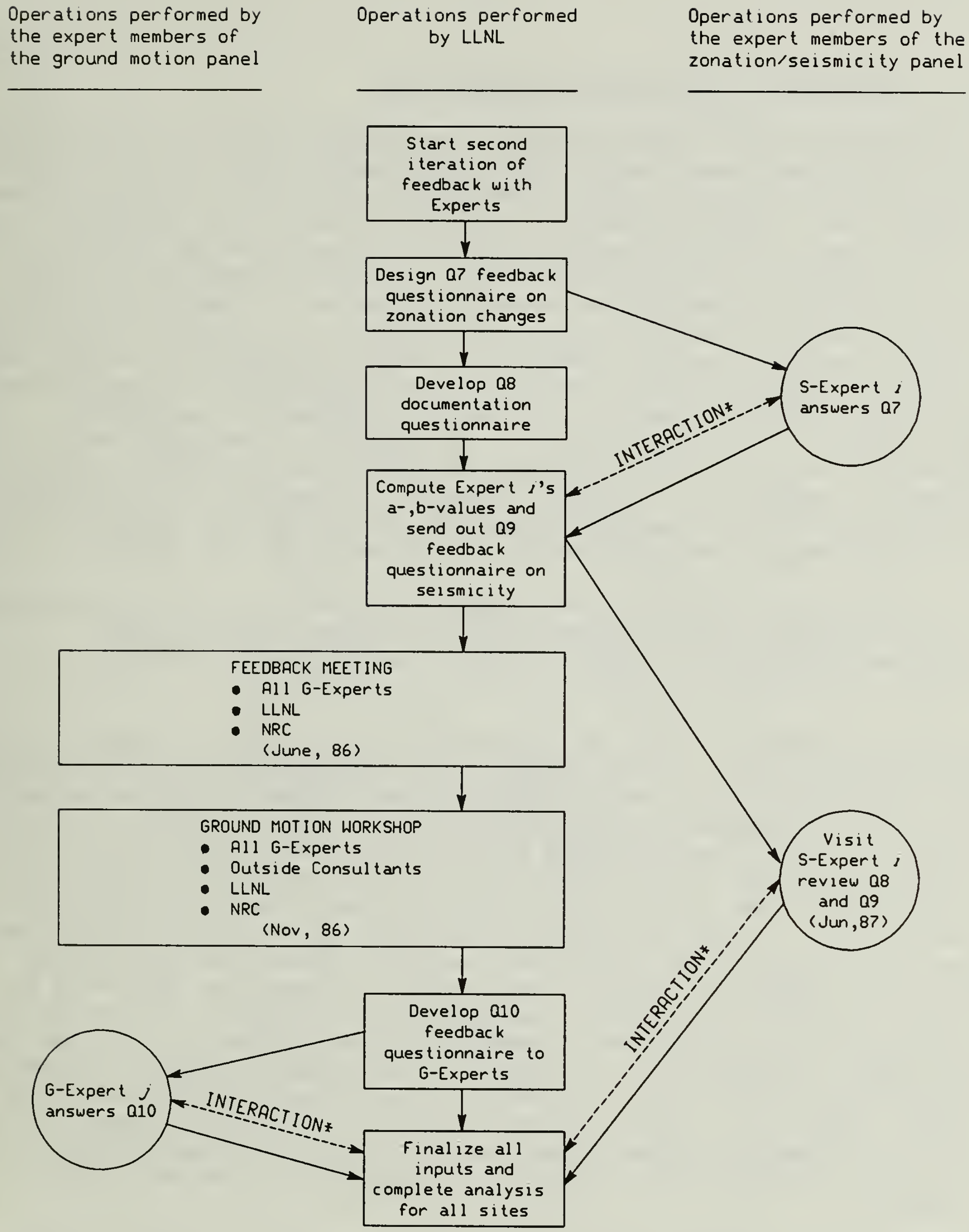
* Mostly by phone or mail, but also meeting in person for a few cases.

Table 3.3. (Continued)



* Mostly by phone or mail, but also meeting in person for a few cases.

Table 3.3. (Continued)



* Mostly by phone or mail, but also meeting in person for a few cases.

Table 3.3. (Continued)

3.2 Development of the Seismic Zonation Maps

A fundamental step in hazard analysis for the SHC project is partitioning the EUS into seismic source zones. Several approaches are possible in the elaboration of a spacial model of earthquake occurrences. The most common approach used in the western U.S. is based on identifying prominent features (such as fault traces) to which historic earthquakes can be associated. Thus it is relatively straightforward to build a spacial model of earthquake occurrences by delineating the areas where the events associated with a given feature will occur in the future. Unfortunately, it is difficult to associate historic events to specific geologic or tectonic features in the EUS. We asked our S-Experts to make use the available geophysical, tectonic, geologic, and historic data to identify zones which are potential sources of earthquakes. In this technique, the contribution of every observable parameter (such as the direction and value of tectonic stresses, gravity anomalies, magnetic flux, geologic features, seismicity) is subjectively evaluated in terms of how much support it provides to the hypothesis of a given zone being a potential source of earthquakes in the future.

The source zones of the SHC are assumed to be areas of seismicity such that all potential earthquakes occurring within an area have the same characteristics such as constant spacial and temporal occurrences and identical maximum magnitudes.

In Q1 the S-Experts of the SHC were asked to use a two step process to define their source zones. In a first step, they were asked to provide a map of the source zones which they believed were the most probable ones, referred to as their best estimate map, based on all the information available to them. Figure 3.1 is an example of such a best estimate map given by one of the S-Experts in the SHC. In a second step they were asked to express their uncertainty in the zonation by assigning degrees of belief to the need to identify (i.e., on the existence of) each zone in their best estimate map. They also could provide alternative source zone boundaries, again with appropriate degrees of belief. Such a set of alternative boundaries for Fig. 3.1 is shown in Fig. 3.2. Based on this information, all the possible combinations of zonations were generated for each S-Expert (using the approach described in Appendix A). The degrees of belief were combined to compute a probability for each map. This probability distribution represented the experts uncertainty in the zonation of the EUS. For each S-Expert the set of all possible maps with their associated probabilities formed the basis for a discrete probability distribution of the maps used in the Monte Carlo simulation.

The distribution of maps were used with the appropriate seismicity parameters (Section 3.3) and ground motion models (Section 3.5) to obtain initial estimates of the seismic hazard using the approach discussed in Section 2 at the ten test sites shown in Fig. 3.3. A feedback meeting was held with all of the S-Experts. At the meeting the S-Experts were provided with the results of our initial analyses Bernreuter et al. (1984) and a number of items were discussed clarifying our methodology, how the S-Experts input was used and to

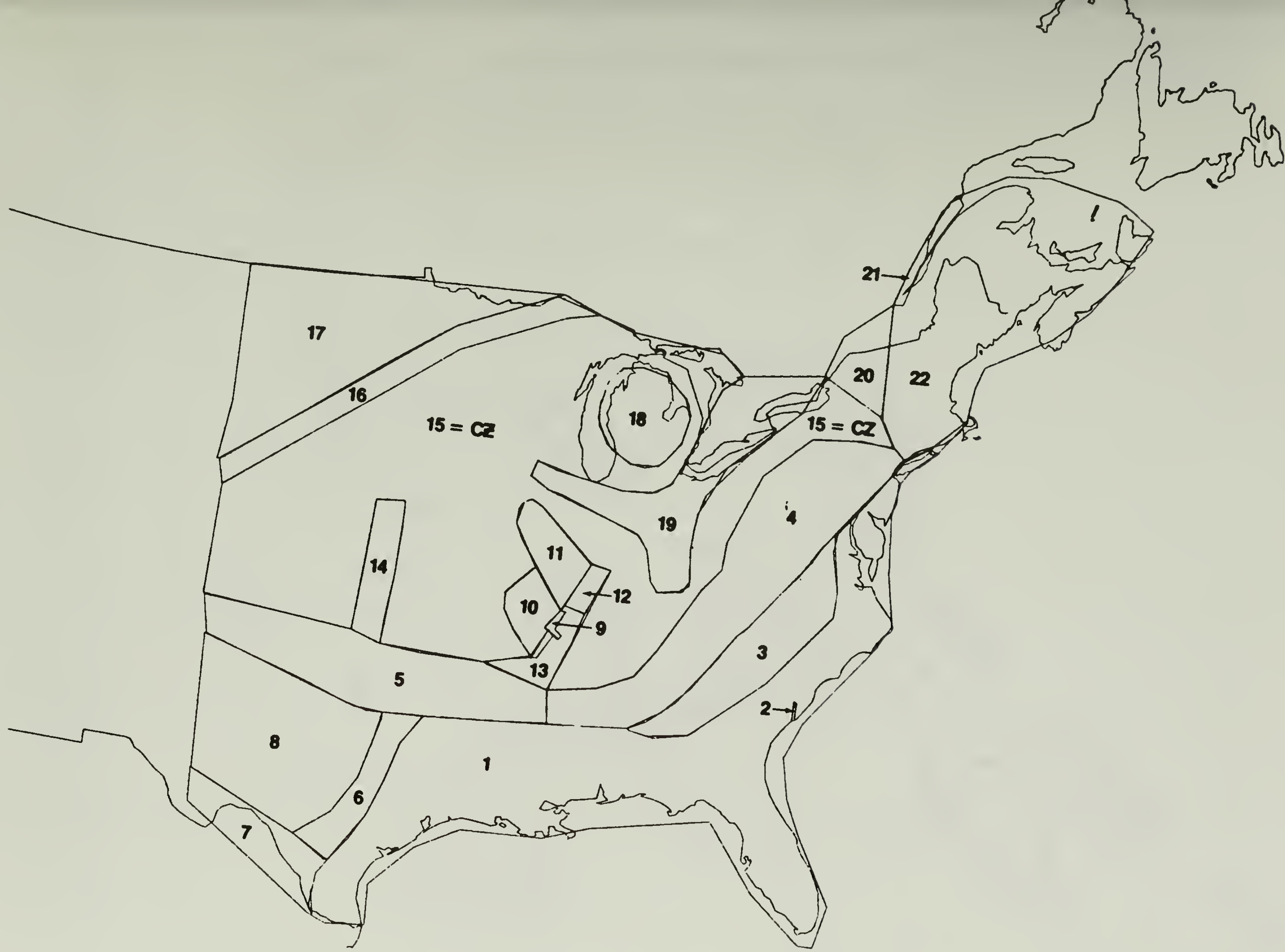


Figure 3.1 Typical example of a zonation map from our S-Experts. Shown is the BE map from S-Expert 1.

Figure 3.2 Alternative zones provided by S-Expert 1.

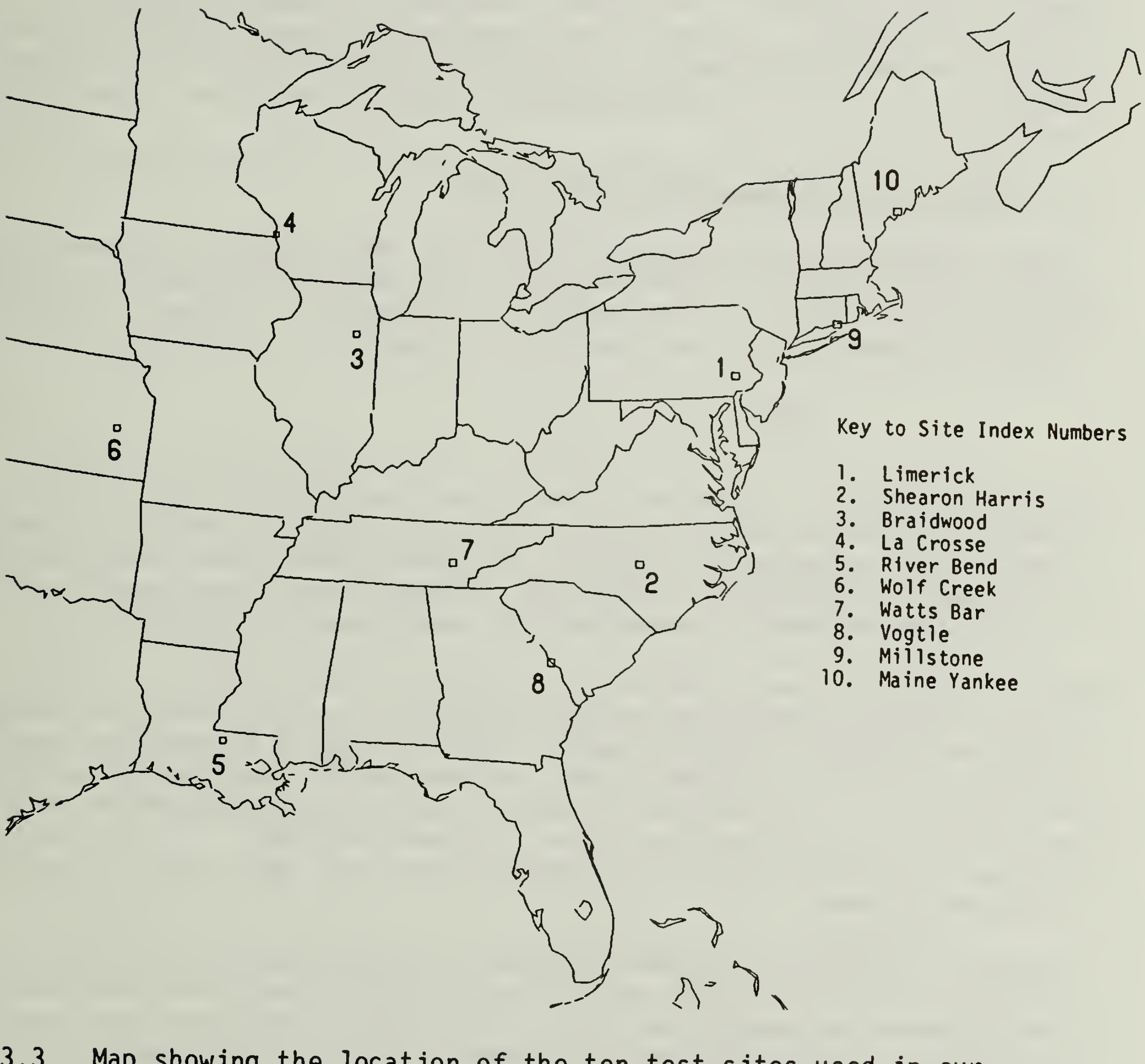


Figure 3.3 Map showing the location of the ten test sites used in our previous analysis, Bernreuter et al. (1984, 1985).

some extent the thinking of various S-Experts. As a result of this meeting Q-5 was sent to the S-Experts in which they were asked to make any changes to their zonation and seismicity parameters they felt were needed in light of the initial results and the discussions at the meeting and in Questionnaire 5.

These updated results from the members of our S-Panel were used in conjunction with the updated input from the G-panel (Q6) to re-compute the hazard at the ten test sites. These results were published in Bernreuter et al. (1985) and sent to our experts. We also provided our expert's with both a draft and final copy of our comparison report, Bernreuter et al. (1987). We then sent the S-Expert Q7 asking them to make any changes they wanted to their zonation. The final maps are given in Appendix B represent any updates or changes they introduced. In summary Experts 3, 6 and 12 introduced completely new sets of zonation. Expert 7 introduced major changes and Experts 4, 11 and 13 made some modifications to existing zones and/or added few new zones. Experts 1,2,5 and 10 did not change their zonation relative to the first feedback.

3.3 Seismicity and Upper Magnitude Cutoff

In most hazard analyses, the seismicity of a zone (Eq. 2.1) is described in terms of the number N of earthquakes per unit of area greater than a given magnitude (or intensity). The number N is customarily related to magnitude by an empirical magnitude recurrence model such as

$$\mathrm{Log}_{10}\ N = a - b\ m\ (\text{or } I), \qquad (3.1)$$

where the seismicity parameters a and b are constant for a given seismic zone, m denotes magnitude, and I is the epicentral intensity. Generally, Eq. (3.1) is modified to account for the fact that every seismic zone is believed to be only capable of producing earthquakes with magnitudes (or intensities) bounded above by some maximum value (called the upper magnitude cutoff, M_U).

In Q2 of the SHC (see Volume VII for details), the experts were asked to model the seismicity of the EUS by providing the a, b, and M_U values for each of the zones they identified in their maps. They were asked to provide a best estimate value (the value which they believe is the most likely to represent the true state of nature) and a range of values which represented their uncertainty in estimating the values of these parameters. This information was used to develop probability distributions which were used in the Monte Carlo simulations.

An expert's estimates of a and b depend on the catalog of events the expert used. In Q2 of the SHC, the experts were expected to choose their own catalog of earthquakes and estimate a and b using whatever technique they deemed most appropriate. The experts were also asked to decide on the type of correction to apply for incompleteness and aftershocks. We did provide the experts with a listing of earthquakes sorted by zones using a catalog we developed based on several catalogs (Bernreuter et al. (1984).

At the feedback meeting and in the follow-up questionnaire (Q5) we put special emphasis on carefully reviewing.

- o How we developed the maps to be used in the analysis from the data provided by each panel members.
- o The definition and importance of the upper magnitude cutoff.
- o Both the desirable and undesirable features of the earthquake recurrence model Eq. (2.1) used in the analysis at the time of the feedback meeting (referred to as the LLNL model) as contrasted to the truncated exponential model.
- o Our concerns about the large ranges of values given for the a and b parameters of the earthquake recurrence model.
- o The possible need for correlation between the a and b parameters during simulation and how such correlation could be introduced.
- o The need to correct the historical catalog for incompleteness and removal of aftershocks.
- o The importance of the experts' estimates of the seismicity in the complementary zone (CZ).
- o The definition of self weights and confidence bounds to reach a common understanding of their meaning.

After the meeting a feedback questionnaire (Q5) was sent to the panel. In this questionnaire the topics covered at the feedback meeting were reviewed and the panel members were requested to update their responses. In this questionnaire the experts were asked to choose between the LLNL recurrence model and the truncated exponential model. The experts were also asked to indicate any correlation that might exist in their estimate of the coefficient a,b. They were asked to choose between no, partial or full negative correlation between and a and b-values of the earthquake recurrence model. The responses were evenly divided between the LLNL model and the truncated exponential model and between no and partial correlation.

The difference between the LLNL and truncated exponential have only a minor impact on the results (Bernreuter et al. (1985)). The LLNL model forces Eq (3.1) to be linear over a range specified by the experts. Whereas the truncated exponential model with a finite upper magnitude cutoff, M_U departs from the above relation near M_U. The differences between the two models is discussed in Q5 and repeated in Q9 and a discussion of our model for partial correlation between the a and b-values is given in Q9 (see Volume VII for details). It should be noted that our final correlation model used in the computations in this report is slightly different (and in our opinion, improved) than the model we used to obtain the results reported in Bernreuter et al. (1985 and 1987). The correlation model also has only minor impact on the computed hazard at a site.

In Q9 we asked , as in Q2, for the a and b-values for each of their zones identified in their final maps. We provided, as before, a sorting of earthquakes in each zone using either the LLNL or EPRI catalog. At the suggestion of our Peer Review Panel, Bernreuter et al. (1985) we departed from our previous approach and provided our S-Experts with estimates for the a and b-values using a uniform methodology that we developed. Our method for estimating the a and b-values is described in Bernreuter et al. (1987) and in Q9. The main features of our method for estimating the a and b-values are: (1) a probability of detection function (with parameters supplied by our S-Expert in Q7) is used to correct for incompleteness; and (2) we convert intensity to a probability distribution rather than to a single magnitude value. The S-Experts had a choice of using the LLNL catalog or the EPRI catalog. They could also choose the approach used to identify aftershocks. We carefully explained to our S-Experts (both in Q9 and in one-on-one meetings) both the good features of our methodology and its limitations. We emphasized that we were providing the a-b-values only as one more source of information, and that we really wanted their judgement.

In Table 3.4 we summarize the model choices made by the S-Experts. In Appendix B we provide their complete input as used in our analysis reported here.

TABLE 3.4
SUMMARY OF MODEL CHOICES OF S-EXPERTS

EXPERT NO.	CATALOG(1)	METHOD FOR(2) ID OF AFTERSHOCKS	RECURRENCE MODEL	TYPE OF CORRELATION	a-b-Valu[e]
1	LLNL	Own	LLNL	Partial	Own
2	LLNL	LLNL	LLNL	None	Own
3	EPRI	EPRI	LLNL	None	Own (3)
4	LLNL	LLNL	LLNL	Full	Own
5	LLNL	Own	LLNL	Partial	Own
6	EPRI	EPRI	LLNL	Full	Own
7	EPRI	Own	LLNL	None	Own
10	EPRI	EPRI	LLNL	None	Own
11	EPRI	Own	LLNL	None	Own
12	EPRI	EPRI	T. Exp.	None	Own
13	EPRI	EPRI	LLNL	None	Own

(1) The catalog the expert selected for us to use to sort the historic seismicity data in each of the expert's zones and in our uniform a-b-value analysis. Several experts indicated that they often relied on other catalogs.

(2) See Appendix B for criteria each S-expert specified to identify aftershocks.

(3) S-Expert 3's a and b- values were very close to the values obtained by the LLNL uniform methodology.

3.4 Documentation

As indicated in Section 3.1 in designing the elicitation process one of our guiding principles was to make sure that all experts had complete flexibility to develop their resources and opinions independent of the other panelists. We wanted everyone to function independently in formulating their opinions and have the flexibility to use analytical methods as well as personal intuition and insight to the degree they felt appropriate. Overall, we wanted to assure that everyone could express their opinions and not be hampered by the need to defend their intuition and insight.

In following our philosophy of eliciting opinions, we did not neglect the need to assure the quality of the experts' responses. We introduced several quality assurance measures into the elicitation process:

- o In the initial choice of experts for inclusion as panelists.
- o As part of the development of the questionnaires used to elicit the expert's opinions, careful consideration was given to the structure of the questions.
- o By interacting with individuals to clarify potential misunderstanding.
- o By having group discussions after the initial elicitation and following these with feedback questionnaires.
- o By introducing qualitative and quantitative comparisons of the expert's inputs with available earthquake data, with subsequent clarification of significant discrepancies.

We are confident that these measures can assure the quality of the final seismicity inputs and the applicability of the resulting estimated seismic hazard. However, a criticism by several members of our Peer Review Panel (Bernreuter et al. (1985)) was the lack of documentation relative to the opinions of our experts. The reviewers felt that better control documentation of the seismicity would add credibility to and facilitate verification of the results of the project. It was suggested, also, that documentation would help to reduce biases and eliminate inconsistencies in the opinions expressed by the experts. It has also been argued that lack of documentation will make it difficult to judge when the experts' present opinions will be outdated, i.e., opinions have changed significantly, so that an updated study should be done.

To meet these criticisms and to ensure that we have a product which is credible and readily applicable to making decisions regarding the relative seismic risks to nuclear power plants located in the EUS, we included a task of developing additional substantiation of the inputs used in the seismic hazard analyses.

To achieve this goal, we sent each of the S-Experts a documentation questionnaire (Q8). In Q8 we explained in some detail our rational for including documentation. We also told the experts that in developing substantiation of the seismicity inputs we are not interested in detailed technical justification for each of their choices. Rather, we are interested in understanding "how" they arrived at their judgements, i.e., what is the general basis of their opinions. We recognized, of course, that the likely situation is that the experts used multiple sources and methods to develop their final opinions. Thus we wanted the experts' to document what their primary sources were and what methods, e.g., graphical, analytical, and logical implications they might have used.

After sending Q8 to each of the S-Experts, we met with them, or discussed by phone, to ensure that they understood the questions and, in general, discussed their responses and in some cases asked for added clarification. If the expert sent in handwritten response we sent the typed version back to him for his review. The S-Experts' responses are given in Appendix A along with our comments relative to the process. These were no modification of the experts input as a result of this documentation process.

3.5 Ground Motion Models

The function of a ground motion model (GM model) is to provide an estimate of the ground motion at a site caused by an earthquake of a known magnitude at a given location. It is very difficult, if not impossible, to develop such a model only on the basis of theoretical principles of physics, mechanics, and a knowledge of the geology and tectonics because many aspects of earthquakes and wave propagation through the earth crust still remain poorly understood. Also, the earthquake energy path is determined by the nature and geometry of the various media (whose properties are very erratic in general) between the source and the site. In addition, the local site characteristics (topography and nature of the soil layers immediately under the site) can have a considerable effect on the level of ground motion observed at a site. Some of the GM models rely entirely on the available strong motion data and are empirical in nature, e.g. Joyner and Boore (1981), Campbell (1981). The more recent models combine a geophysical formulation with the available strong motion data, e.g., Atkinson (1983), Boore and Atkinson (1987).

Our approach to model this large uncertainty in the estimation of the ground motion and the correction due to local characteristics at any EUS site given an earthquake of magnitude m at a distance d from the site was to use multiple experts input. The choice of which GM models and which correction for local soil conditions should be used and their weights relative to other candidate models was left to our Ground Motion Panel members (G-Experts). Each G-Expert, like the S-Experts, provided his individual opinion, and as described in Section 2.5, only in the final step were the inputs from all G-Experts combined. Each G-Expert was asked to provide the GM model which was in his view the "best" model. He was also asked to provide up to six additional models which, in his view, modeled his modeling uncertainty. We indicated that the selection of GM models and weights was to model their uncertainty about the location of the median estimate and not the variability between earthquakes of the same magnitude. This variability was modeled by assuming that the uncertainty in the estimate of the ground motion between earthquakes has some distribution (generally lognormal) and the G-Experts provided the distribution to use and estimates for the parameters defining the distribution.

As can be seen from Table 3.3 a number of informational meetings/workshops were held with the G-Experts. The main purposes of these meetings were to discuss our methodology and how we were using the input that the S and G-Experts provided as well as to discuss the areas of greatest uncertainty, controversial issues and to describe various GM models (both strong and weak points). In our GM questionnaires (Q4, Q6 and Q10), in addition to a listing of the various models we also provided the G-Experts with comparisons between the models and additional discussion of main issues. Refer to Vol VII which contains the questionnaires and, in particular, to Section 6 of Q10 which lists all of the GM models. In this report for ease of reference we identify each GM model by the ID number given in Q10 which is given in Volume VII.

In addition, as the final analysis showed that the ground motion Expert 5's input lead to hazard estimates substantially different from the estimates obtained with the other four G-Experts (see Volume VI, Section 2.3), we performed an additional feedback with Expert 5. The result of this feedback confirmed that the input given by Expert 5 had been correctly interpreted and that the results were consistent with the Expert's thinking.

Table 3.5 lists the peak ground acceleration (PGA) models and Table 3.6 lists the 5 percent damped relative velocity spectral models selected by the G-Experts from the tabulation of GM models given in Q10, along with the weight the G-Experts gave for each model. To help the reader, the models are identified in Tables 3.5 and 3.6, both by an ID, as in the questionnaire Q10, and by a simple description. It should be noted that the spectra are computed at five periods: 0.04s, 0.1s, 0.2s, 0.4s and 1.0s. In addition we denote which GM models the various G-Experts considered the "best estimate" (BE) GM model. As discussed in Q10 the experts were allowed to provide different models for the four regions shown in Fig. 2.3. Only G-Expert 2 gave different weights and BE models for different regions as indicated in Tables 3.5 and 3.6.

Both G-Experts 2 and 3 elected to provide their own parameters for model RV-5A, RV-5V and RV-5RS. G-Expert 2 selected the Boore-Atkinson RV model but with

$$Q = 1000f^{0.3}$$

and the relation between the seismic moment M_o and m_b as

$$\log M_o = 2\, m_b + 13.2 \qquad m_b \geq 4.5$$
$$\log M_o = m_b + 17.7 \qquad m_b < 4.5$$

G-Expert 3 set the relation between seismic moment M_o and corner frequency f_c as

$$M_o f_c^{\ 3.5} = 3. \times 10^{23}$$

and between moment magnitude M and m_b

$$M = 2.72 - 0.28m_b + .13\ m_b^2$$

G-Expert 2 set the depth (D) to be used in the GM models to be a function of magnitude:

$D = 2.5\ m_b - 2.5$ if m_b is greater or equal to 5.0
$D = 5\ m_b - 15$ if m_b is less than 5.0

G-Expert 3 set the depth term for the response spectrum model to be a function of period T:

$D = 10.3$ km $T < 0.15s$

$$D = 5.022 - 1.073\ \left(\frac{1}{T}\right) + 0.708\ \left(\frac{1}{T}\right)^2 - 0.064\ \left(\frac{1}{T}\right)^3$$

for

$0.159 \leq T \leq 1.05$

In Tables 3.5 and 3.6 we also give the overall aggregated weight of each GM model normalized by the G-Experts self weights given in table 3.7.

The best estimate PGA models are plotted in Fig. 3.4 for magnitudes of 5 and 7. The remaining PGA models are plotted in Fig. 3.5 also for magnitudes of 5 and 7. It should be noted that the base case used for both Figs. 3.4 and 3.5 is rock. Site correction factors are discussed later, however, it is important to note that for the PGA models, the median correction factor to convert the models selected from rock to generic deep soil is 1.0 except for the model selected by G-Expert 5, G16-A3, where the correction is significant as shown by comparing Fig. 3.6 to Fig. 3.4.

The BE spectral models are plotted for magnitudes of 5 and 7 at a distance of 25 km in Fig. 3.7 and the remaining models are also plotted for magnitudes of 5 and 7 at a distance of 25 km in Fig. 3.8. All models are for the rock base case.

It should be noted that all of the RV models listed in Tables 3.5 and 3.6 have a complex form which cannot be directly used in hazard analysis programs. It was necessary to use the analytical form for the various RV models to generate values of acceleration, velocity or spectral velocity as a function of m_b and distance. Then a model more suitable for use in hazard analysis programs, e.g.,

$$\log a = C_1 + C_2\ m_b + C_3\ m_b^2 + C_4\ m_b^3 + C_5\ R + C_6\ \log R$$

was fit to the computed values of ground motion by a least squares fit. Generally our fits were in two parts, from 0 to 100 km and from 100 km to 1200 km. All fits had less than a 5 percent error, generally much better. However, to get the error term small some times required relatively complex functional forms. These functional forms were developed by a trial-and-error use of stepwise fitting packages and examination of the residuals of proposed fits.

TABLE 3.5

PGA MODELS AND WEIGHTS SELECTED BY THE G-EXPERTS

MODEL (1) ID	DEPTH (2) km	G-EXPERTS ID X1 All Regions	X2 Region 1	X2 Regions 2 - 4	X3 All Regions	X4 All Regions	X5 All Regions	Total Aggregated (3 Weight Reg. 1	Reg. 2-
RV-1A	8.	0.25	-	-	0.4BE	0.4BE(4)	-	0.2	0.2
RV-2A	8.	0.25	-	-	0.3	-	-	0.12	0.12
RV-5A (5)	(6), 8.	-	0.4BE	0.3	0.3	-	-	0.17	0.12
G16-A3	Epicentral	-	-	-	-	-	1.0BE	0.20	0.20
SE-1A	(6)	-	0.3	0.4BE	-	-	-	0.16	0.18
SE-1A	8.	0.25	-	-	-	0.25	-		
SE-2A	8.	0.25BE	-	-	-	0.25	-	0.1	0.1
Comb-1A	-	-	0.3	0.3	-	0.1	-	0.07	0.07

Notes

(1) Model IDs are the IDs given in Section 6 of Q10 in Vol. VII.

(2) Some models only differ by the average depth used in the GM model to compute the distance.

(3) Aggregation includes the G-Experts' self-weights given in Table 3.7.

(4) BE- Best estimate GM model.

(5) G-Experts 2 and 3 provided their own parameters for the RV-model as described in the text of Section 3.5.

(6) G-Expert 2 set the depth as a function of magnitude- refer to the text of Section 3.5.

(7) The combined weight is given as the models only differ by the depth term.

TABLE 3.5 (Continued)
PGA MODELS IDENTIFICATION
(SEE Q10 IN VOLUME VII)

RV-1A:	Boore-Atkinson model - based on physical assumptions source spectrum shape and random vibration theory (rock model).
RV-2A:	Toro-McGuire - based on physical assumptions, source spectra shape and random vibration theory. Different physical values as in RV-1A (rock model).
RV-5A:	Same as RV-1A or RV-2A, different parameter values (rock model).
G16-A3:	Trifunac correlation of PGA versus epicentral intensity and Gupta-Nuttli attenuation of the intensity. Entirely data based. Applies to rock, deep soil or intermediate.
SE-1A:	Semi-empirical Nuttli (1986) model. For $f_c - M_o$ (corner frequency - seismic moment) slope of 4 (soil model).
SE-2A:	Semi-empirical Nuttli (1986) model for $f_c - M_o$ slope of 3 (soil model).
Comb-1A:	An empirical model based on all available intensity and strong motion data, developed by Prof. Veneziano, 1986. Applied to rock or soil.

TABLE 3.6

5 PERCENT DAMPED RELATIVE VELOCITY SPECTRAL MODELS
AND WEIGHTS SELECTED BY THE G-EXPERTS

MODEL ID (1)	DEPTH km	G-EXPERTS ID						Total Aggregated Weight	
		X1 All Regions	X2 Region 1	X2 Regions 2-4	X3 All Regions	X4 All Regions	X5 All Regions	Reg. 1	Reg. 2
RV-1RS	(3)	-	-	-	0.4BE	0.4BE	-	0.20	0.20
RV-1RS	8.0	0.25							
RV-2RS	(3)	-	-	-	0.3	-	-	0.12	0.12
RV-2RS	8.0	0.25							
RV-5RS(5)	(3),(6)	-	0.3	0.3	0.3	-	-	0.12	0.12
TL-RS	E	-	-	-	-	-	1.0BE	0.2	0.2
NH-SE1A,V	(6)	-	0.3	0.4BE	-	-	-	0.17	0.19
NH-SE1A,V	8.0	0.25	-	-	-	0.3	-		
NH-SE2A,V	8.0	0.25BE	-	-	-	0.3	-	0.1	0.1
NH-(7)	(6)	-	0.4BE	0.3	-	-	-	0.09	0.06

Notes

(1) Model IDs are the IDs given in Section 6 of Q10 in Vol VII.

(2) Normalization includes the G-Experts self-weights given in Table 3.7.

(3) G-Expert 3 made the depth a function of frequency - see text in Section 3.5.

(4) The combined weight is given as the models only differ by the depth term.

(5) G-Experts 2 and 3 provided their own parameters for the RV-model as described in the text in Section 3.5.

(6) G-Expert 2 set the depth as a function of magnitude- see text in Section 3.5.

(7) G-Expert 2's RV-5A and RV-5V models are used to anchor the acceleration and velocity legs of the Newmark-Hall spectral shape.

TABLE 3.6 (Continued)
IDENTIFICATION OF SPECTRAL MODELS
(SEE Q10 IN VOLUME VII FOR MORE DETAILS)

RV-1RS:	Boore-Atkinson model. Based on physical assumptions, source spectrum shape and random vibration theory. Applies to rock.
RV-2RS:	Toro-McGuire model. Same as RV-1RS, different parameter values. Applies to rock.
RV-5RS:	Same as RV-1RS or RV-2RS, customized by G-Experts 2 and 3. Applies to rock.
TL-RS:	Trifunac and Lee (1985) empirical model.
NH-SE1A,V:	Newmark-Hall constructed with semiempirical models SE-1A and SE-1V (same as SE-1A but for velocity) for acceleration and velocity.
NH-SE2A,V:	Same as NH-SE1A,V, but uses SE-2A and SE-2V for acceleration and velocity.
NH-	RV-5A and RV-5V (same as RV-5A but for velocity) are used to anchor the Newmark Hall spectral shape.

TABLE 3.7

G-EXPERTS SELF-WEIGHTS

EXPERT	SELF-WEIGHT
1	10
2	9.5
3	9
4	7
5	9

Plot Symbol	GM Model No.
1	RV-1A
2	RV-5A (X2)
3	G16-A3
4	SE-1A
5	SE-2A

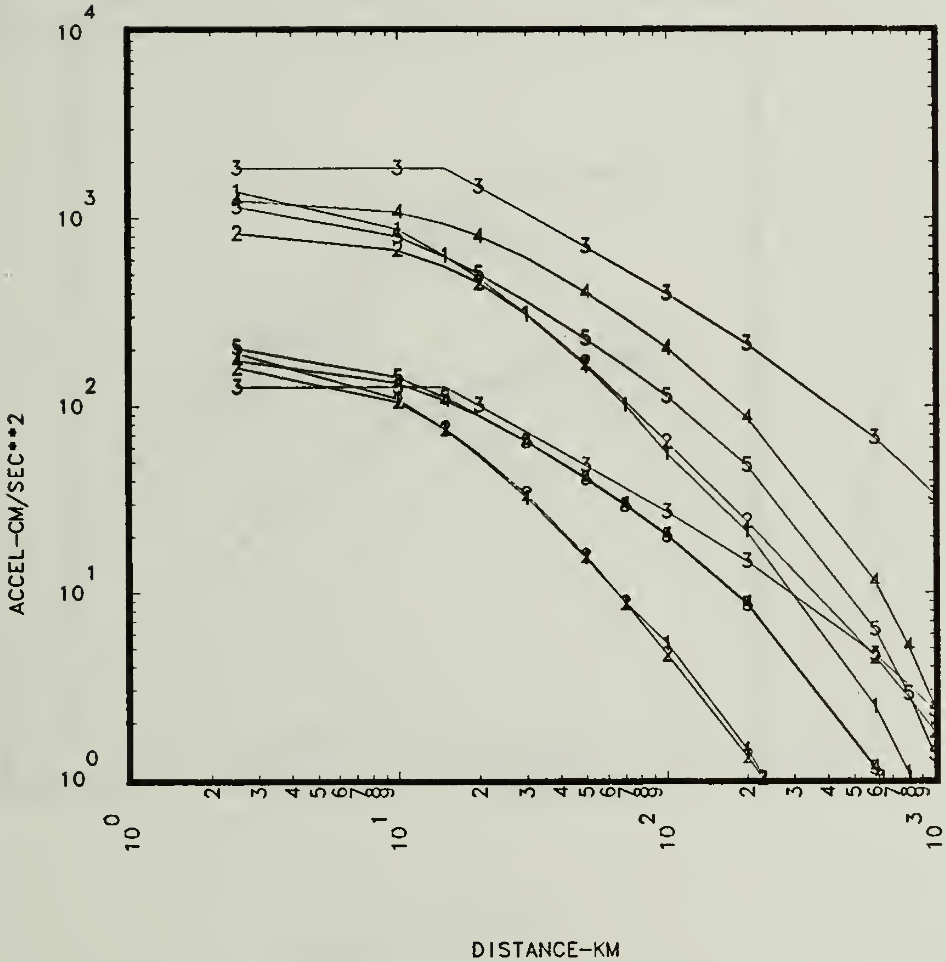


Figure 3.4 Best estimate PGA models listed in Table 3.5 plotted for magnitudes of 5 and 7. Rock base Case.

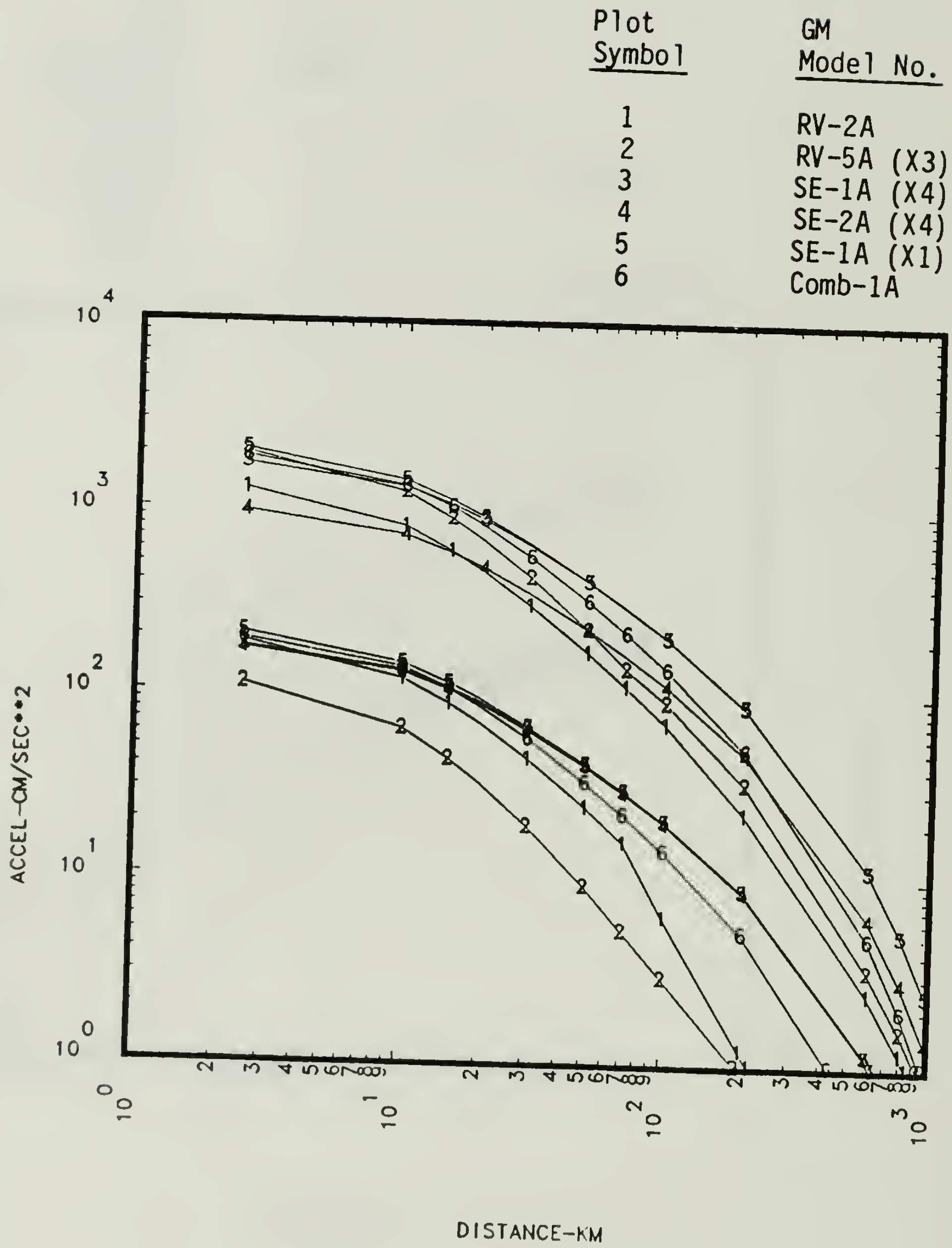


Figure 3.5 Remaining PGA models listed in Table 3.5 plotted for magnitudes of 5 and 7. Rock base case.

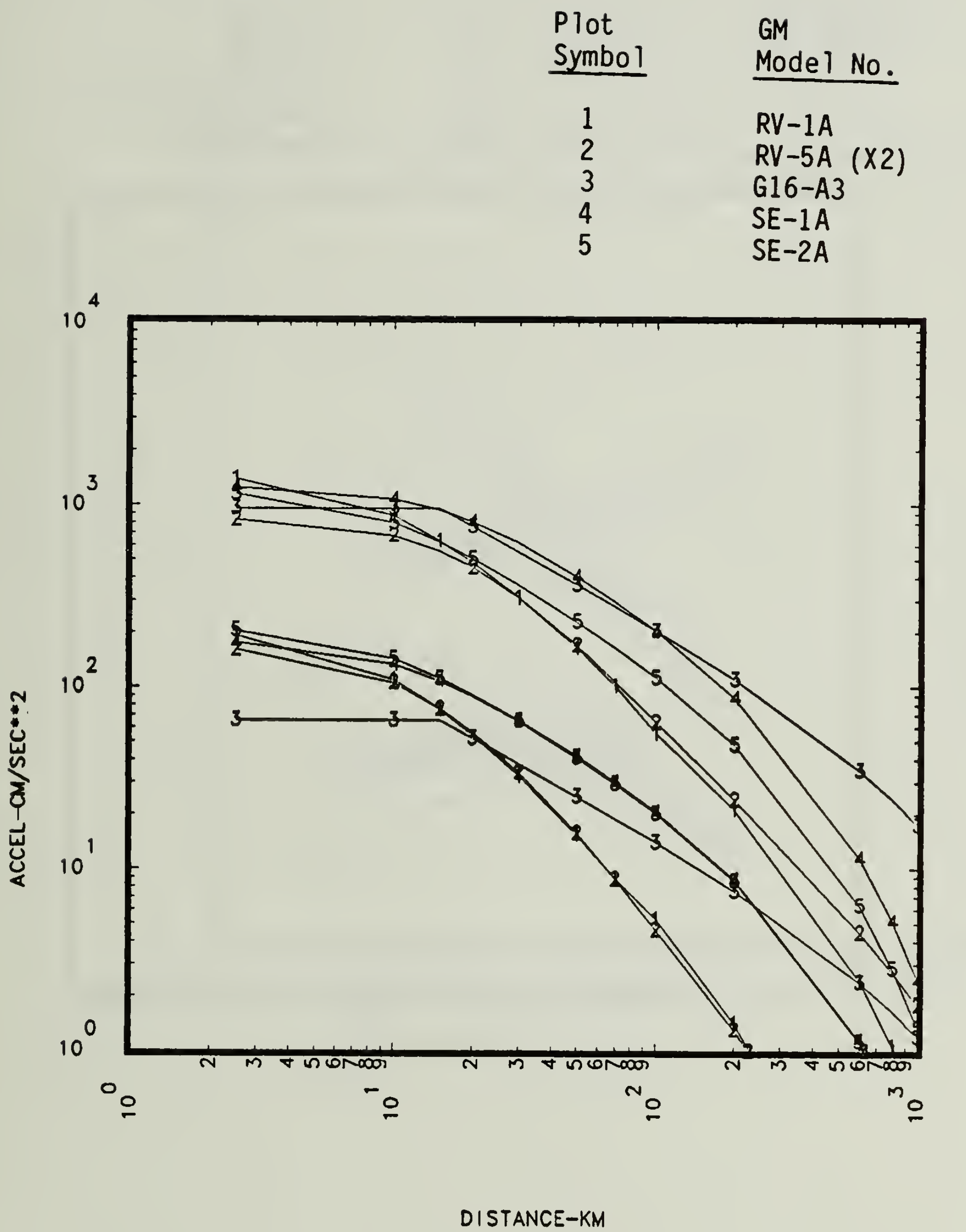


Figure 3.6 Best estimate PGA models corrected to generic deep soil for magnitudes of 5 and 7.

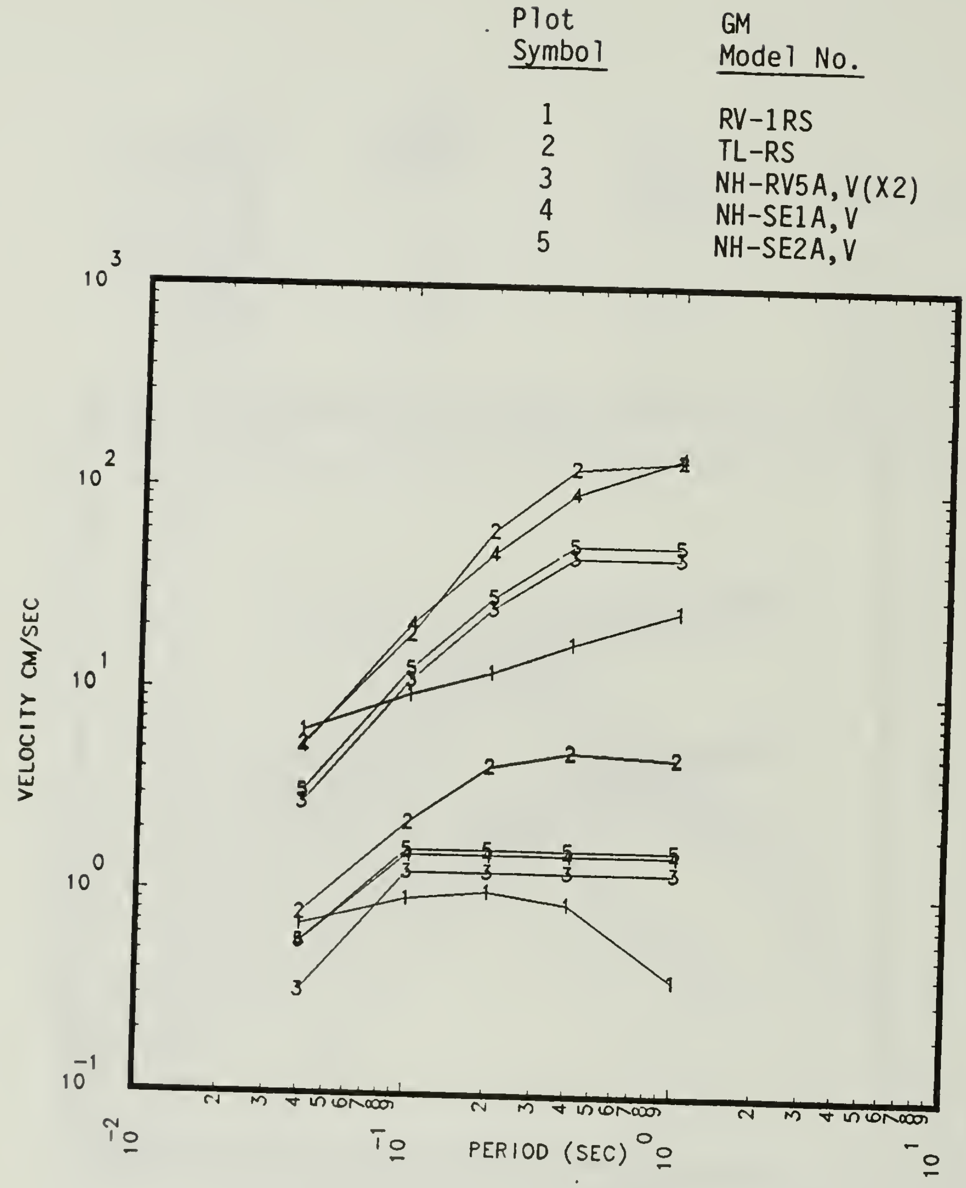


Figure 3.7 Best estimate 5 percent damped relative velocity spectra models listed in Table 3.6 plotted for magnitudes of 5 and 7 at a distance of 25 km. Rock base case.

Plot Symbol	GM Model No.
1	RV-2RS
2	RV-5RS (X3)
3	RV-5RS (X2)
4	NH-SE1A,V
5	RV-1RS (X1)
6	RV-2RS

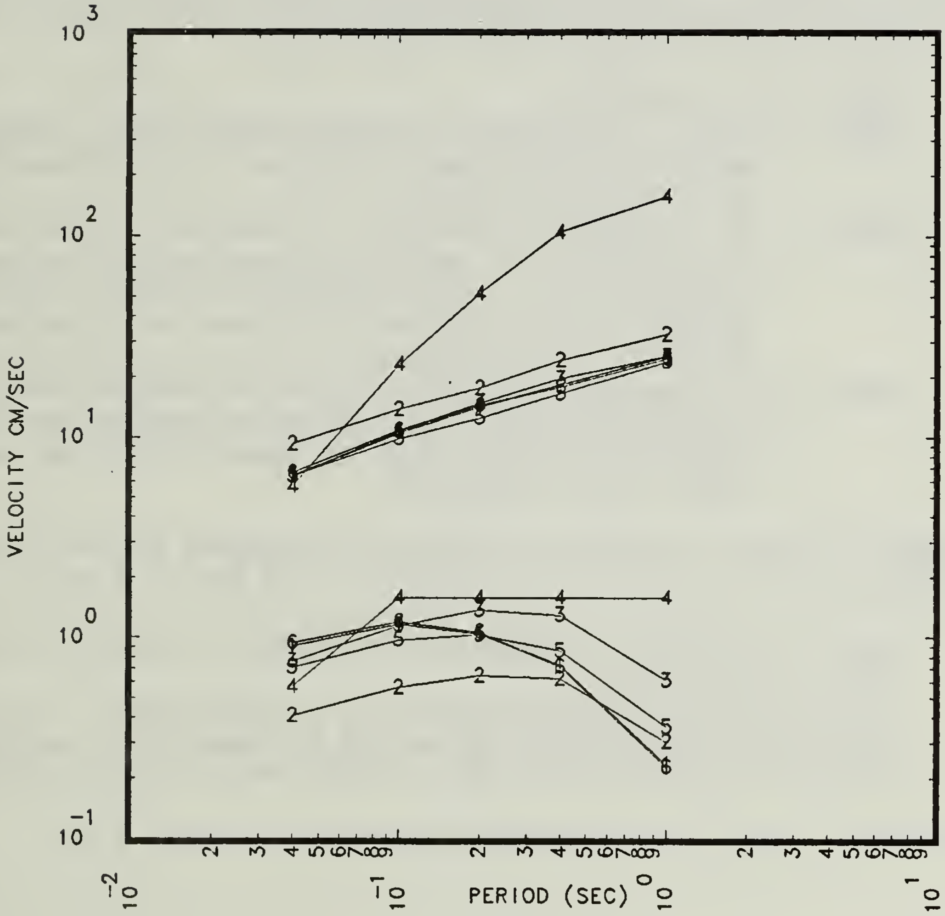


Figure 3.8 Remaining 5 percent damped relative velocity spectra models listed in Table 3.6 plotted for magnitudes of 5 and 7 at a distance of 25 km.

3.6 Random Uncertainty and Truncation of GM Estimates

Each G-Expert was asked to provide an estimate of the random uncertainty to be used in the ground motion attenuation relationships. The influence of the local site was not to be included if the expert chose to use the category correction approach discussed in the next section. In Table 3.8a we provide the G-Expert values. Except where noted for G-Expert 5, the values listed in Table 3.8a refer to the standard deviation of the natural logarithm of the GM parameter. Each G-Expert was also asked to select a method to model the possible truncation of the uncertainty distribution and/or maximum possible GM motion possible based on the following choices:

- o Model 1: No truncation.
- o Model 2: There is an absolute maximum acceleration, independent of magnitude and distance, which will not be exceeded. This is the Type 1 saturation.
- o Model 3: The maximum acceleration is a function of magnitude and distance; this is modeled by assuming the maximum acceleration is a fixed number of standard deviations from the mean in the lognormal distribution of the GMP's. This is the Type 2 saturation.
- o Model 4: For any magnitude and distance the maximum acceleration is the minimum of an absolute maximum and a fixed number of standard deviations from the mean; this is an envelope of Type 1 and 2 saturation.

The 3 types of limits, drawn as a function of distance R for a fixed magnitude m, are depicted in Fig. 3.9. It is observed from Fig. 3.9 that:

- o Type 1, an absolute maximum acceleration, a_1, results in the horizontal curve C_1.
- o Type 2, the maximum acceleration is a fixed number, n, of standard deviations from the mean curve, a(m,R), results in curve C_2.
- o Type 3, the envelope of Type 1 and 2, results in the curve C_3.

The G-Experts' choices for truncation are given in Table 3.8b

TABLE 3.8a

G-EXPERT'S CHOICE FOR THE RANDOM UNCERTAINTY, SIGMA [1] FOR THE GM MODELS

Expert	BE PGA	Range PGA	BE Spectra	Range Spectra
1	0.35	0.3 - 0.4	0.35	0.3 - 0.4
2	0.55	0.4 - 0.7	0.55	0.4 - 0.7
3	0.5	0.4 - 0.7	0.6	0.4 - 0.8
4	0.5	0.35 - 0.65	0.5	0.35 - 0.65
5	0.7	0.7 - 0.9	(2)	(2)

(1) Standard deviation of the natural logarithm of the GMP.

(2) G-Expert 5's spectral model TL-RS is not a lognormal model.

TABLE 3.8b

G-EXPERTS' CHOICE FOR TRUNCATION OF THE GROUND MOTION VARIATION

Expert	Method to Truncate PGA	Max PGA (cm/s/s) and/or N Sigmas	Method to Truncate Spectra	Max S_v and/or N Sigmas
1	1	None	1	None
2	4	2500/2.5	3	/2.5
3(1)	1	None	1	None
4	1	None	1	None
5	3	4	1(2)	None

(1) G-Expert 3 noted that he preferred Method 4 for truncation, but did not know what the limits were.

(2) G-Expert 5 indicated that the spectral model he selected TL-RS is not a lognormal model and the distribution used in model TL-RS adequately accounts for the truncation of the distribution.

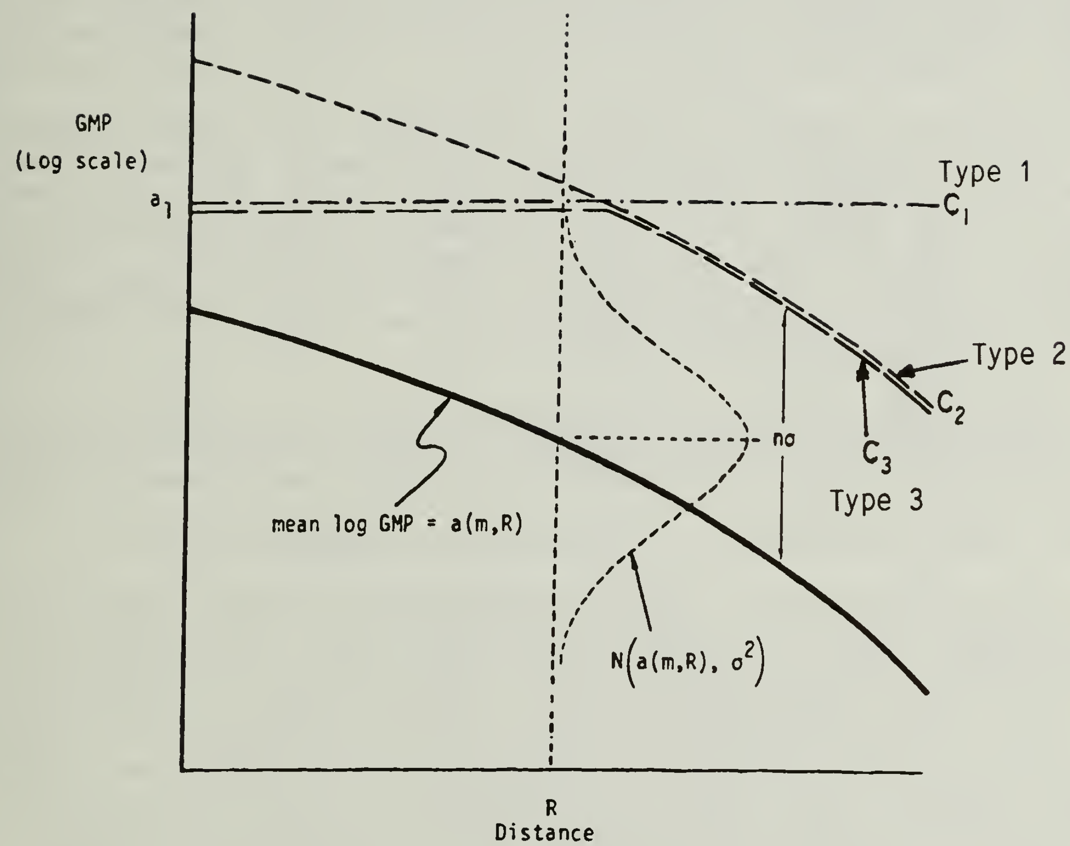


Figure 3.9 Illustration of the three types of models considered to model the physical saturation of ground motion. The random variation of the logarithm of the ground motion parameter (GMP) is modeled by a normal distribution with mean GMP (m,R) and a standard deviation σ.

3.7 Correction for Local Soil Conditions

We asked each of our G-Experts to provide relative weights for each of the following three possible correction approaches for local soil conditions:

1. No correction applied
2. Apply a simple correction, either the site is soil or rock.
3. Apply our categorical correction approach.

Then, as outlined in Section 2, for each G-Expert we used a Monte Carlo approach to perform the uncertainty analysis. For each trial we draw randomly (relative to the weights provided) one of the GM models, then draw (relative to the weights provided) one of three possible correction approaches to correct the selected GM model from its base case for local soil conditions.

The no correction approach requires no discussion. The simple correction approach is a bit more complex. Any specific GM model is assumed to be either a rock or a soil model. If the site's category is the same as the base case of the GM model then no correction is applied. If not, then a simple constant correction factor is applied. Figure 3.10 shows several typical "simple" correction factors. The G-Experts were asked to select the simple correction term for us to use with their GM models the percentage of the time that the simple correction approach is used.

With this methodology, the site correction is not tied to any specific ground motion in particular. However, in the case of G-Expert 5, only one ground motion model was selected (see Tables 3.5 and 3.6), and G-Expert 5 chose the simple correction, which is the same as the one developed in the ground motion model. Thus, for G-Expert 5, only one type of correction was used.

The case is more complicated when the categorical correction approach is used. First, the site is assumed to be in one of the eight categories listed in Table 3.9. Then, as discussed in Section 5 of Q6 and Q10 a set of correction factors were developed in the following manner. Figures 3.11a and 3.11b illustrate our procedure. To get a set of time histories to use in the analysis, we selected a set of 20 time histories recorded at rock sites with various magnitudes and distances to incorporate the uncertainty from the source and travel path effects in the analysis. The site response was calculated by assuming one-dimensional vertically propagating SH waves. Sites were modeled as a system of horizontal layers of infinite extent. Viscoelastic material properties for each layer were assumed for the shear modulus, density, Poisson's ratio, and material damping. The input was one of 20 rock outcrop time histories. The site response for each of the S1, S2, S3, T1, T2, T3 and deep soil categories was computed using the SHAKE Program.

To account for uncertainties in material properties and earthquake characteristics, we performed repeated deterministic analyses, each analysis simulating an earthquake occurrence. By performing many such analyses and by varying the values of the input parameters, a mean response and its coefficient of variation was obtained. Variability in the seismic input is included by sampling from the twenty time histories to obtain a different earthquake time history for each simulation. Variability in the dynamic modeling was introduced by sampling sets of input parameters (mainly shear wave velocities of soil and rock, damping ratio of soil and the depth of soil deposit) from assumed probability distributions for each simulation. A lognormal distribution for each input parameter was assumed for this study.

Using the above data we developed two median correction factors as a function of spectral frequency (to correct the GM model from rock to the site's category or from generic soil to the site's category) and the uncertainty in our estimate of the median in the following manner. For the rock base case, we simply computed the correction factor by taking the ratio of the computed spectrum at the top of each soil column to the input rock spectrum. For each category this resulted in a set of 20 correction factors. It was found that a lognormal distribution could be used to model the uncertainty in the estimated correction factor with $\sigma = 0.5$. This value constitutes our opinion of the best value for this parameter. This choice came from the analysis described above and some judgement on the amount of reduction to apply to the values found to remove non site effects, such as path and source effects, after a study performed for NRC under a separate project, where these effects were specifically studied and quantified (Bernreuter, Chen and Savy, 1986). Figure 3.12 shows the resultant smoothed median correction factors for the till-like categories relative to rock, and Fig. 3.13 shows them for the sand-like sites relative to rock. The median correction factors are plotted at each of the five spectral periods (0.04, 0.1, 0.2, 0.4 and 1.0 sec) and connected by straight lines to make it easier to follow the general trends. Also shown in Fig. 3.13 are the correction factors for deep soil relative to rock. Note that the correction factors for PGA are plotted at 0.01 sec in both Figs. 3.12 and 3.13.

Our original plan (see Q10) was to carry along two sets of correction factors, one set relative rock and one set relative to generic soil. We did not do this because it would have required an extensive rework of the logic of our computer program and only a single family of soil base case models (Nuttli's latest model labeled SE-1 and 2 in Q10). The only difference between SE-1 and 2 is the scaling with magnitude which is selected using theoretical considerations. The PGA models SE-1A and SE-2A were "converted" to a rock base case using the median correction factor (1.0) found in our analysis for PGA between generic soil and rock sites and the velocity model was converted to a rock base case in a similar fashion, however, for the velocity a correction factor of $V_{soil}/V_{rock} = 1.7$, as found in our analysis, was used.

In the Monte Carlo uncertainty analysis when the categorical correction approach is selected the correction factor is simulated based on the assumed lognormal distribution for the particular category, with the median and the standard deviation derived for that distribution.

Table 3.10 lists the site correction methods selected by the G-Experts and their weights, given by the G-Experts for use in the Monte Carlo analysis. It can be seen from Table 3.10 that the categorical approach is very heavily weighted. This is a change from our previous study, Bernreuter et al. (1985) where the categorical approach carried an aggregated weight of about 0.53 for spectra and 0.46 for PGA. Thus the site effect will be more significant in the results presented in this report than in our previous report, Bernreuter et al (1985).

TABLE 3.9

DEFINITION OF THE EIGHT SITE CATEGORIES

	CATEGORY	DEPTH
Generic Rock		
(1)	Rock	N/A
Sand Like		
(2) Sand 1	S1	25 to 80 ft.
(3) Sand 2	S2	80 to 180 ft.
(4) Sand 3	S3	180 to 300 ft.
Till-Like		
(5) Till 1	T1	25 to 80 ft.
(6) Till 2	T2	80 to 180 ft.
(7) Till 3	T3	180 to 300 ft.
Deep Soil		
(8)	Deep Soil	N/A

TABLE 3.10

G-EXPERTS' WEIGHTS FOR SITE CORRECTION APPROACH

Expert	No Correction	Simple Correction	Categorical Correction
1	0.	0.	1.0
2	0.	0.	1.0
3	0.	0.	1.0
4	0.	0.	1.0
5	0.	1.0	0.
Aggregated Weight	0.	0.2	0.8

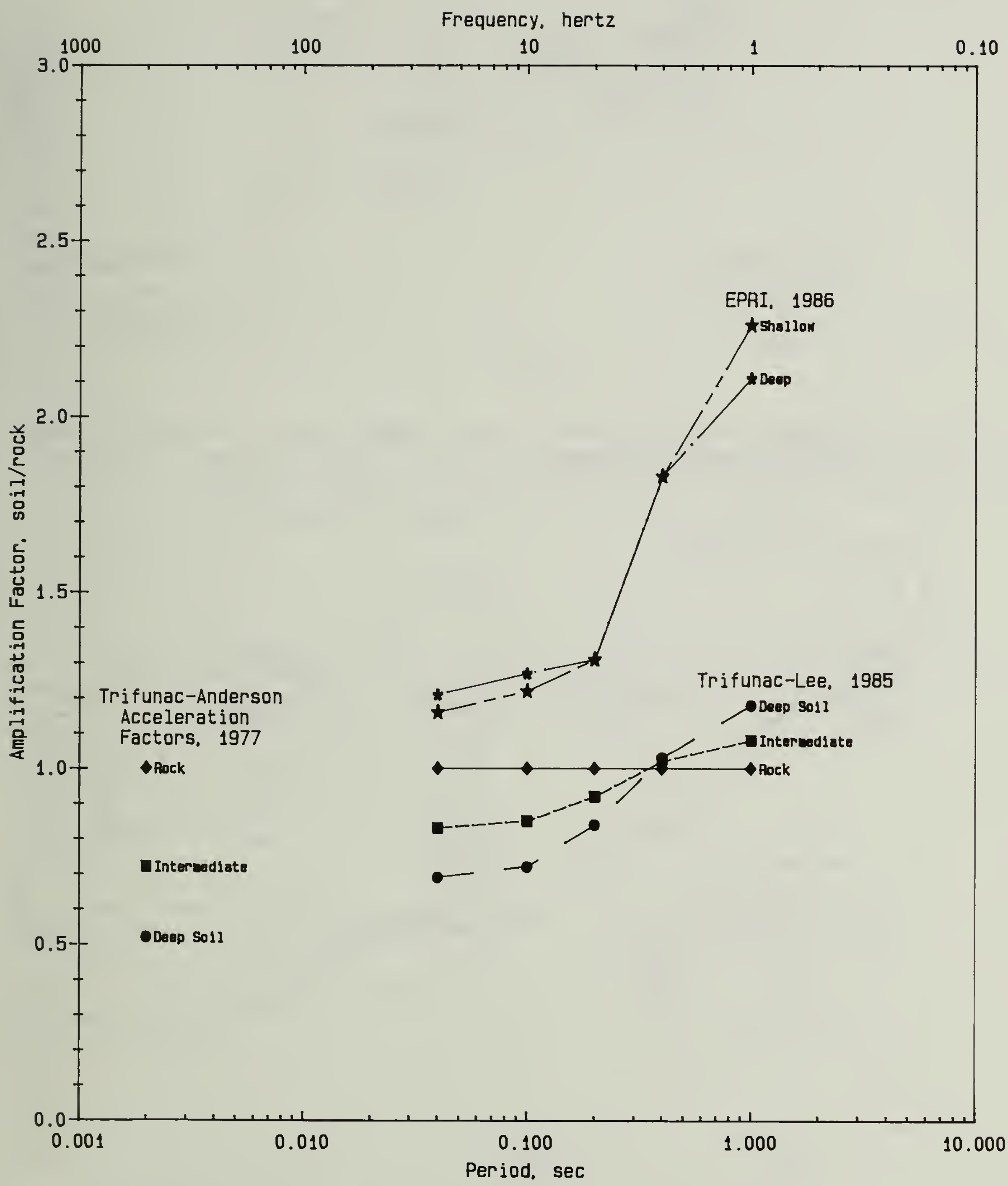


Figure 3.10. Simple correction factors relative to rock.

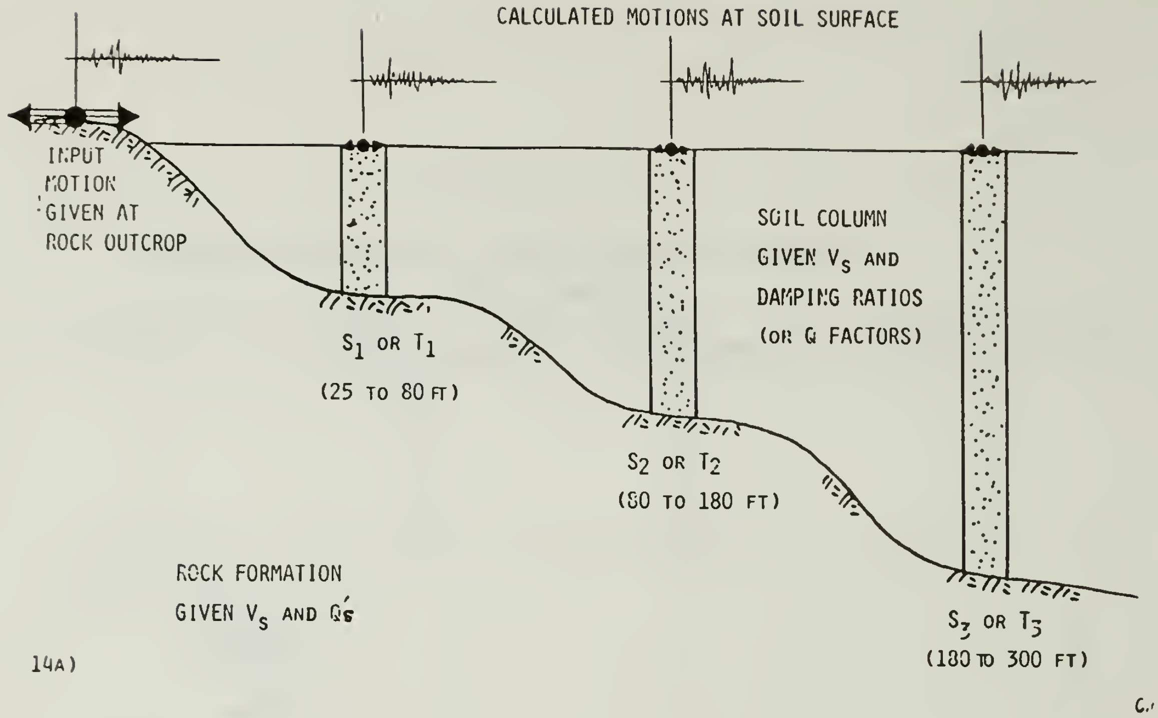


Figure 3.11a Schematic representation of our computational procedure to model site correction factors.

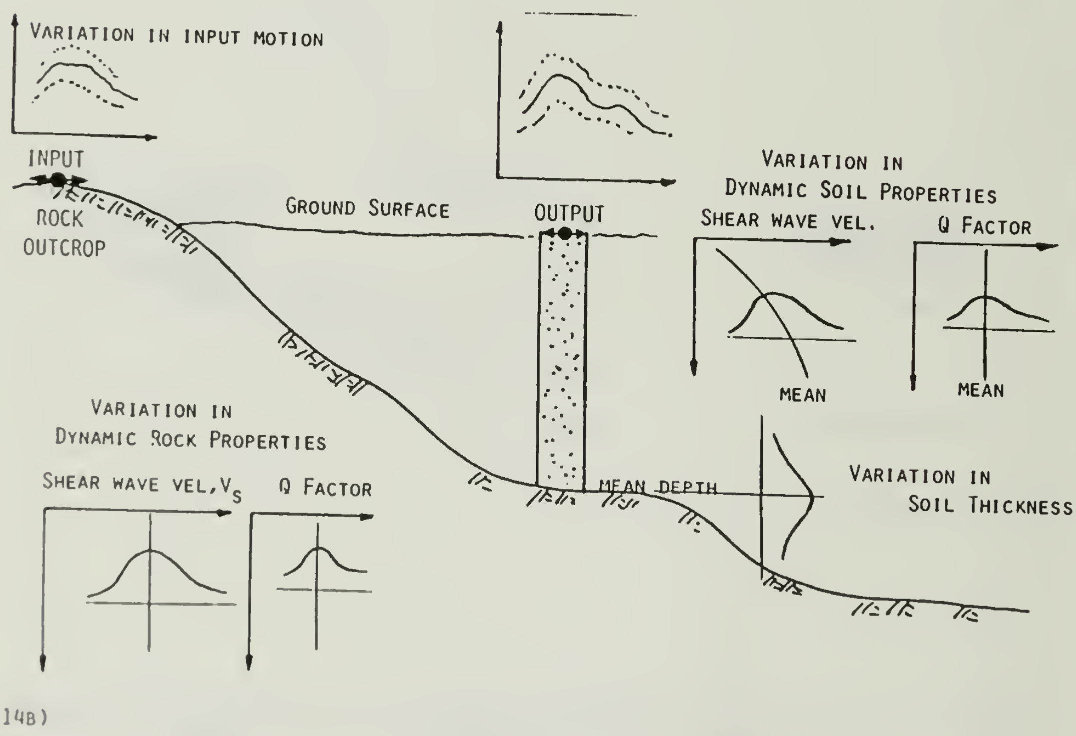


Figure 3.11b The physical parameters used in the 1-D analysis are drawn from probability distributions.

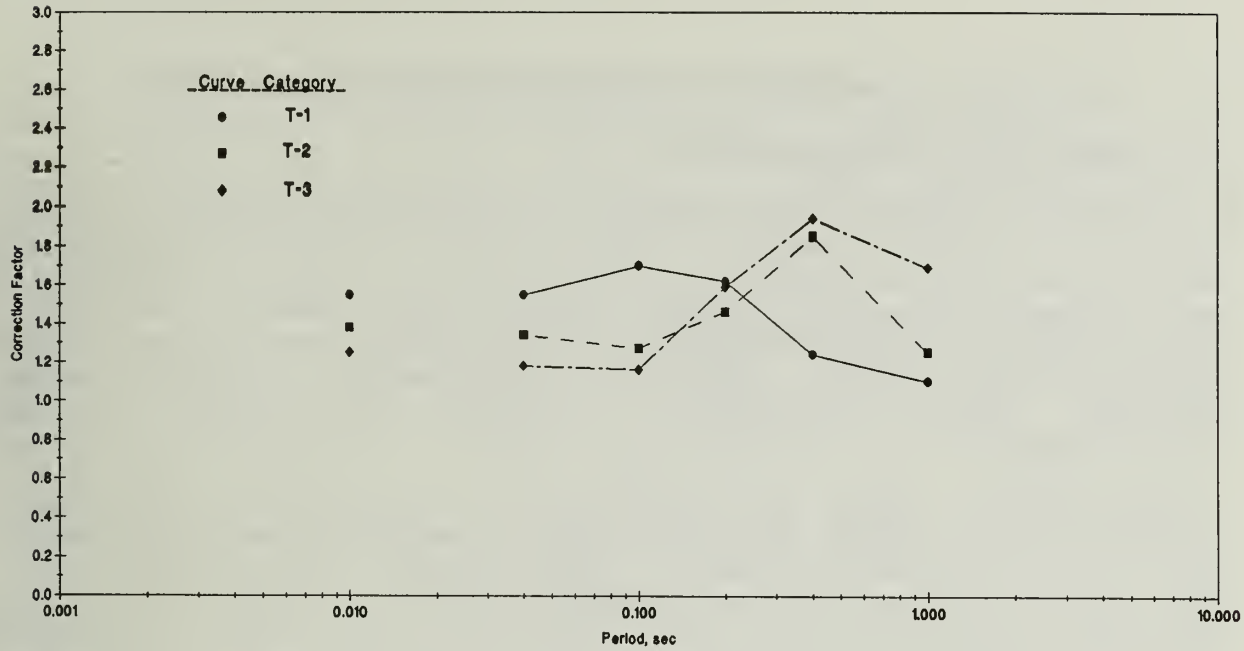


Figure 3.12 Smoothed median correction factors for the till-like categories listed in Table 3.9 relative to rock. The PGA correction factors are plotted at 0.01s.

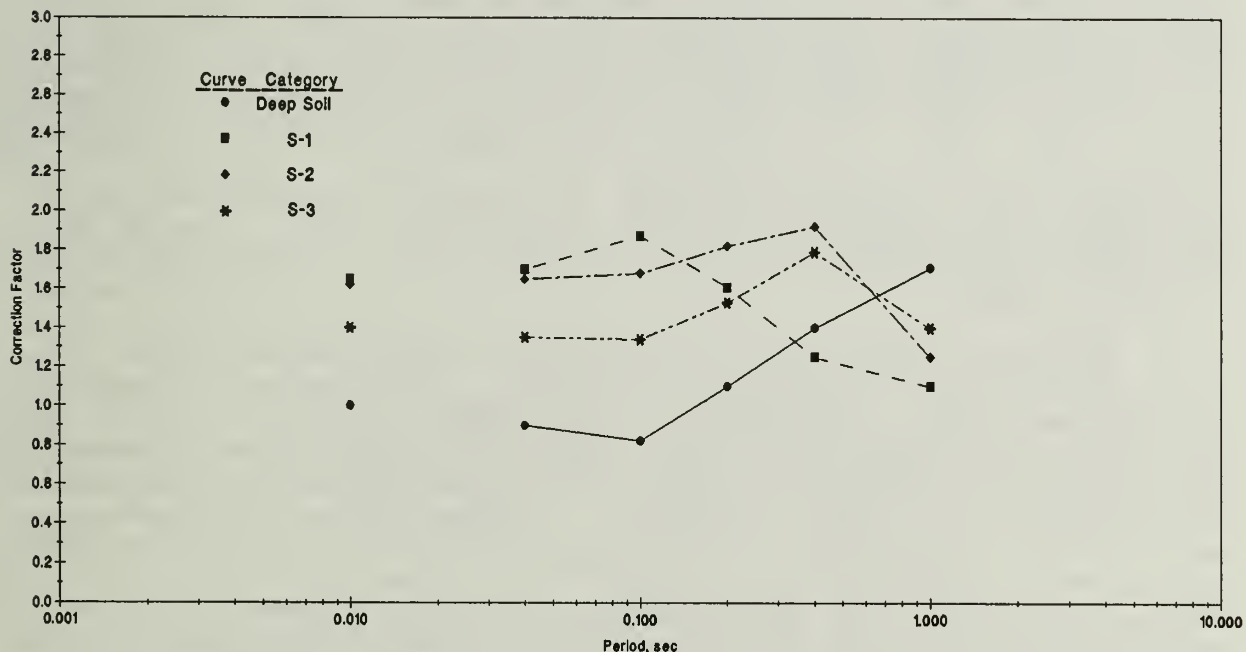


Figure 3.13 Smoothed median correction factors for the sand-like categories listed in Table 3.9 relative to rock. Also shown are the correction factors for deep soil relative to rock. The PGA correction factors are plotted at 0.01s.

SECTION 4: COMPARISON TO PREVIOUS RESULTS AND OTHER STUDIES

4.1 Comparison to Previous Results

As indicated in Section 3 only S-Experts 1,2 and 5 made no changes in their zonation or seismicity parameters, whereas S-Experts 3,6 and 12 introduced completely new maps and naturally all new seismicity parameters. Experts 4,11 and 13 introduced some small changes in zonation and a number of changes in the seismicity parameters whereas S-Expert 7 introduced major changes, without completely redoing his maps. Expert 10 introduced changes in his seismicity parameters. Even more significantly there has been major changes in the input from our G-Experts.

In addition to the changes introduced by our S and G-Experts it should be noted that for this report the integration over magnitude starts at a lower bound of 5.0 whereas in our previous study we started at a lower bound of 3.75. This change generally has a significant effect on the results as discussed in Bernreuter et al. (1987). These three factors must be considered in order to compare our current results to our previous results. In order to isolate the source of any differences in the estimates of the seismic hazard at our ten test sites between the updated results and our previous results we first compare the estimate of the seismic hazard at each of the ten test sites using the new input from our S-Experts to the results obtained using the input from S-Experts given in Bernreuter et al (1985). The ground motion model used was the modified Nuttli PGA model used in the comparison to EPRI results discussed in detail in Bernreuter et al (1987). This model is very similar to the model SE-1A selected by several G-Experts. Figures 4.1 and 4.2 show typical comparisons of the constant percentile hazard curves (CPHCs) for PGA between the new and previous results at the Braidwood and the Millstone sites. Our new seismicity input from the S-Experts results in an increase in the estimate of the seismic hazard at five sites (Shearon Harris, Braidwood, LaCrosse, River Bend, Wolf Creek) and a decrease at the other five sites. The largest differences are at LaCrosse and River-Bend and the smallest difference is at Watts Bar. Given the uncertainty in the estimate, as measured by say the 15th and 85th percentile CPHC there is relatively little change in the aggregated results between our previous input and the new final updated input from our S-Experts.

At the individual S-Expert level some very major difference have been introduced by some of the changes introduced by the S-Experts. For example, in Fig. 4.3a the best estimate hazard curves (BEHC) for PGA for each of the S-Experts for the Braidwood site based on the updated input given in Appendix B are plotted and in Fig. 4.3b the BEHC based on the input given in Appendix A of Bernreuter et al. (1985) are plotted. If these figures are compared several notable differences are observed. First, it is noted that the BEHC for S-Expert 11 (plot symbol B) is significantly lower in Fig. 4.3a (new) than in Fig. 4.3b (old). This large change occurs because S-Expert 11 changed his zone 10. Previously, zone 10 extended northward and included the site. In the updated map (see Appendix B) zone 10 was reshaped and no longer includes the Braidwood site. Thus the BEHC for S-Expert 11 is now significantly lower than that resulting from the older input from S-Expert 11. It is also seen from comparion of Figs. 4.3a and 4.3b that new BEHC from S-Expert 12 (plot symbol c) is also significantly lower than before. Previously, S-Expert 12 had a zone 10 which included the Braidwood site. The contribution too the seismic hazard from zone 10 was significant, thus here is a significant decrease in the BEHC for S-Expert 12 with his current zonation which does not have a zone near Braidwood as compared to his previous zonation near the Braidwood site.

In Fig. 4.4a we plot the BEHC for the S-Experts based on their updated input given in Appendix B for the Millstone site and in Fig. 4.4.b based on their previous input given in Bernreuter et al (1985). The most significant change at the Millstone site is for S-Expert 7. Previously, S-Expert 7's input resulted in a PGA BEHC at a Millstone site that was one of the highest (Fig. 4.4.b) whereas based on his current updated input S-Expert 7's BEHC is the lowest at the Millstone site. In both the old and the new zonation for S-Expert 7 the Millstone is in a zone 24. Currently S-Expert 7 has set the upper magnitude cutoff in zone 24 at 5.75 whereas previously he set it at 6.5. In addition, currently the absolute value of the b-value is higher than before, this coupled with a new a-value results in the rate of magnitude five events being approximately a factor of five lower than previously and at magnitude 5.75 the difference in rate of events greater than 5.75 is even larger.

Figures 4.1 and 4.2 show that the 15th, the 50th (median) and the 85th CPHC also remain relatively stable. The 85th CPHC shows less change than the 15th CPHC. The range of variation at the ten test sites is reasonably covered by Figs. 4.1 and 4.2.

The above comparisons suggest that if common ground motion models are used then the CPHCs are a reasonably stable estimate of the seismic hazard at a site for the same set of experts over a period of time; however, individual experts results might significantly change. This is in agreement with conclusions reached in Bernreuter et al. (1985).

It is of some interest to examine the effect that introducing the uncertainty in the GM models has on the results. In Fig. 4.5 and Fig. 4.6 we compare the CPHCs at the Braidwood and Millstone sites for the case where the CPHCs are computed using all of the GM models and weights given in Table 3.5 and the updated seismicity input given in Appendix B to the case of the single GM model used to generate Figs. 4.1 and 4.2. It should be noted that the differences in the 50th CPHCs between the case when all of the GM models are used and only one GM model is used is solely dependent on the choice of the single GM model used, hence no meaning can be attached to the difference between the 50th CPHCs. However, what is significant is the difference between the bounds as represented by the 15th and 85th CPHCs. It can be seen that uncertainty introduced by the GM models is significant.

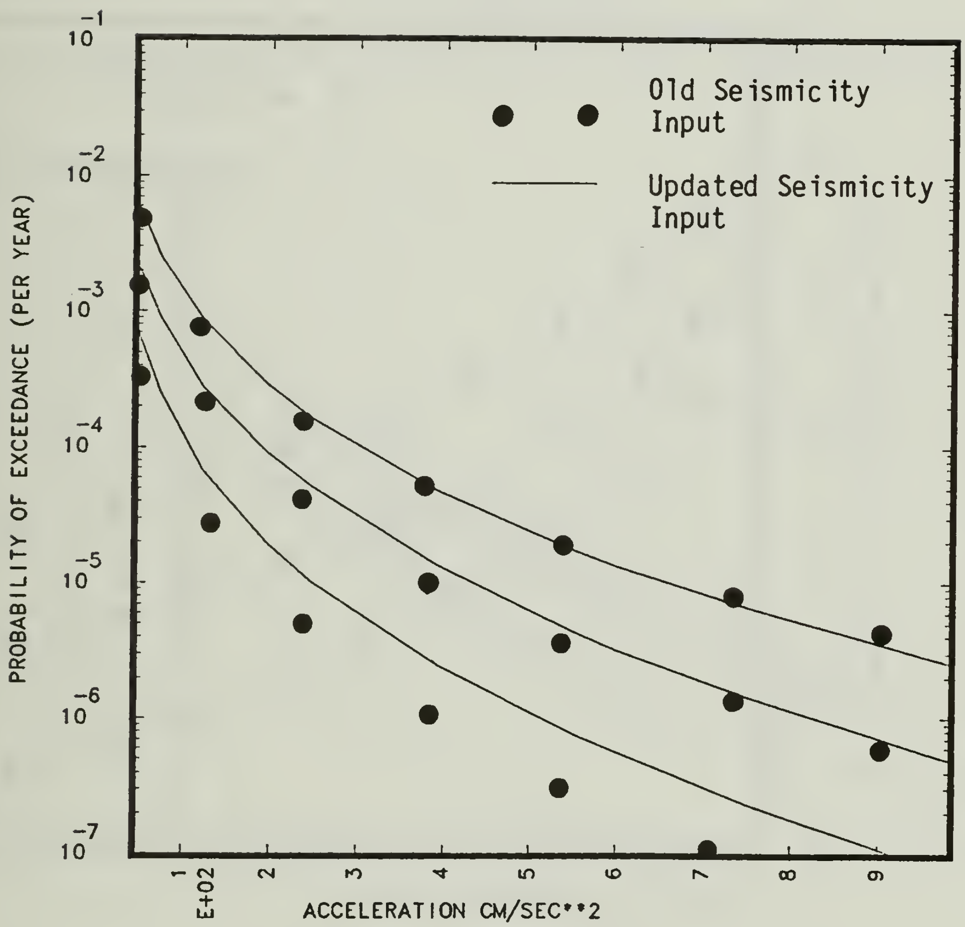
In Figs. 4.7 and 4.8 we compare the CPHCs obtained using the latest updated input to CPHCs obtained using our previous input as reported in Bernreuter et al. (1985), for the Braidwood and Millstone sites. The difference between the old and new results on Figs. 4.7 and 4.8 are typical of the difference between the old and new results at the other test sites.

Given all of the changes in both the seismicity and PGA models there is remarkably little difference between the current and previous results. However, when the spectral models are considered we see a much greater difference between the current results as compared to our previous results as is illustrated in Fig. 4.9. In Fig. 4.9 we compare the 1000 year return period constant percentile uniform hazard spectra (CPUHS) at the Braidwood site for the case when the GM models, seismicity input given in Appendix B, and weights in Table 3.6 are used to the results given in Bernreuter et al. (1985). There is a reasonable agreement in the average level of the spectra between the old and new results. However, Fig. 4.9 shows clearly that the new set of ground motion spectral models has introduced higher spectral values at high frequencies (low periods) and lower spectral values at low frequencies (high periods in the range of one second). The reason for this is the very major shift in the shape of spectral models selected by the G-Experts. In Bernreuter et al. (1985) all of the available models had a shape similar to the Newmark-Hall models (models denoted by NH-in table 3.6) and the Trifunac-Lee model (the model denoted by TL - Table 3.6); however, in the updated input from the G-Experts, the random vibration models (the models denoted by RV- in Table 3.6) carry a weight of 0.44 which means they are used almost half the time. The RV models are generally much lower at the longer periods than the Newmark-Hall type models as can be seen from Fig. 3.8. Thus it is not surprising to observe a significant difference between the updated CPUHS and our previous results in the longer period range.

4.2 Comparison to Other Studies

In Bernreuter et al. (1985 and 1987) a number of comparisons were made between the results obtained using the input from our S and G-Panels to the results of other studies. In Bernreuter et al. (1985, 1987) we concluded that if the same GM models and lower bound of integration are used then generally our previous results were in good agreement with the results obtained from other studies, EPRI (1985b), Algermissen et al. (1982), Yankee Atomic Electric Company (1983) ERTEC (1983) and Dames and Moore (1983). In addition we showed that our previous results were in good agreement with the hazard estimates obtained using a historical method, Veneziano et al. (1983) and Bernreuter et al. (1985). Because of the good agreement between our previous results and the updated results there is no need to repeat the comparisons made in Bernreuter et al. (1985, 1987) and the same conclusions are valid.

PERCENTILES = 15., 50. AND 85.



BRAIDWOOD

Figure 4.1 Comparison of the 15th, 50th and 85th percentile CPHCs for PGA between the new results based on the updated input from the S-Experts described in Section 3 and our previous results given in Bernreuter et al. (1985) for the Braidwood site. Only a single PGA model (modifed Nuttli) was used.

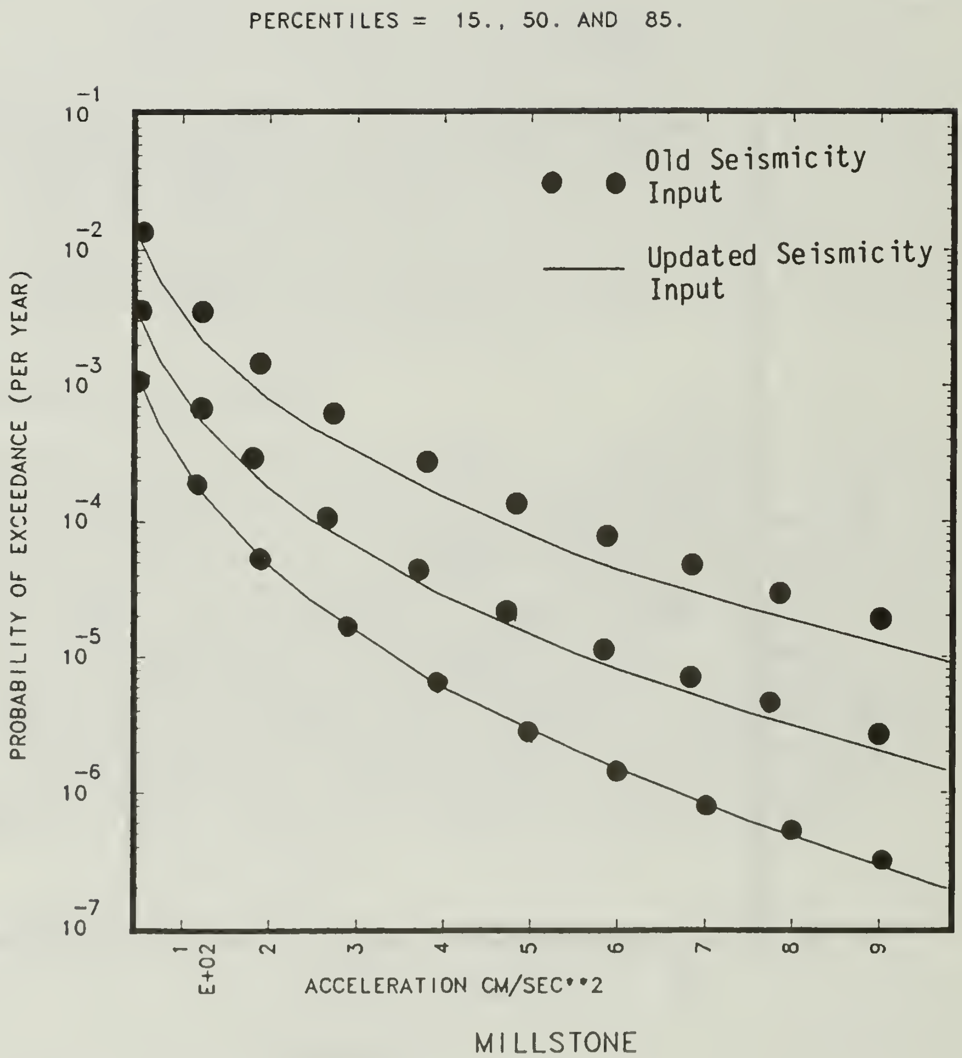
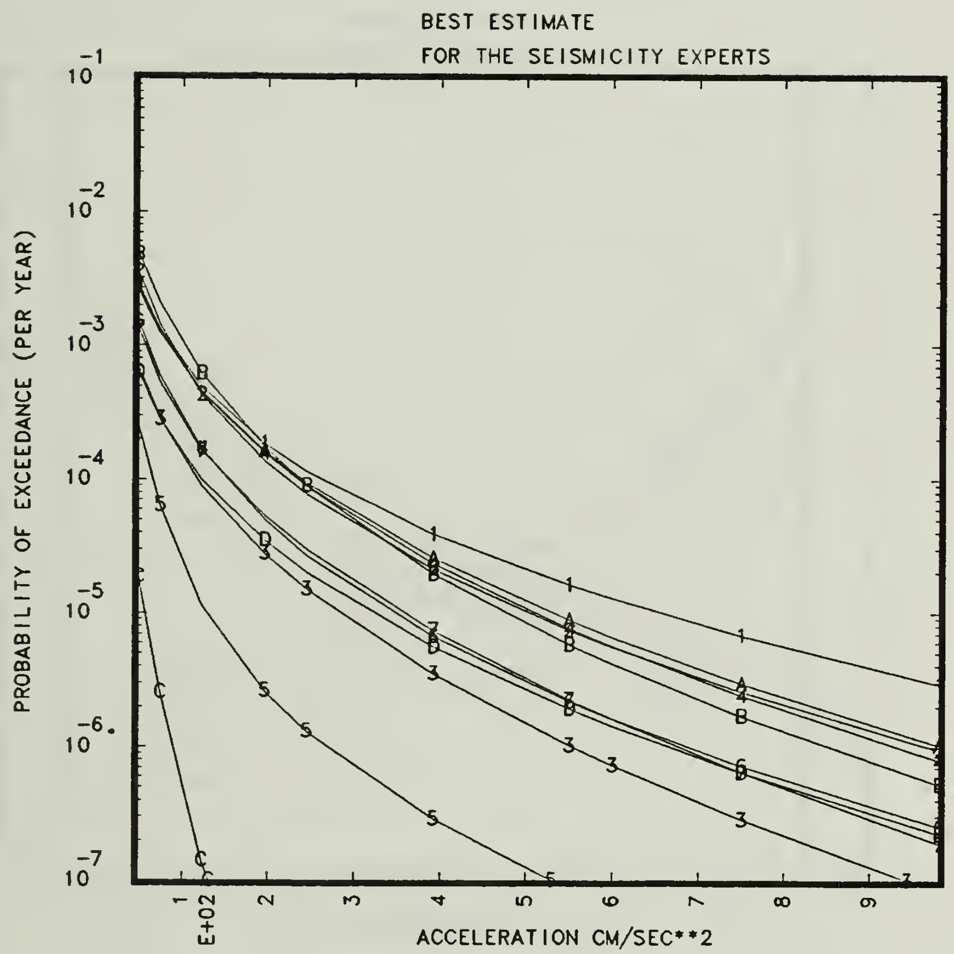


Figure 4.2 Comparison of the 15th, 50th and 85th percentile CPHCs for PGA between the new results based on the updated input from the S-Experts described in Section 3 and our previous results given in Bernreuter et al. (1985) for the Millstone site. Only a single PGA model (modifed Nuttli) was used.



BRAIDWOOD

Figure 4.3a BEHCs for PGA for the Braidwood site per S-Expert based on the updated input provided by the S-Experts. Only a single PGA model (modified Nuttli) was used.

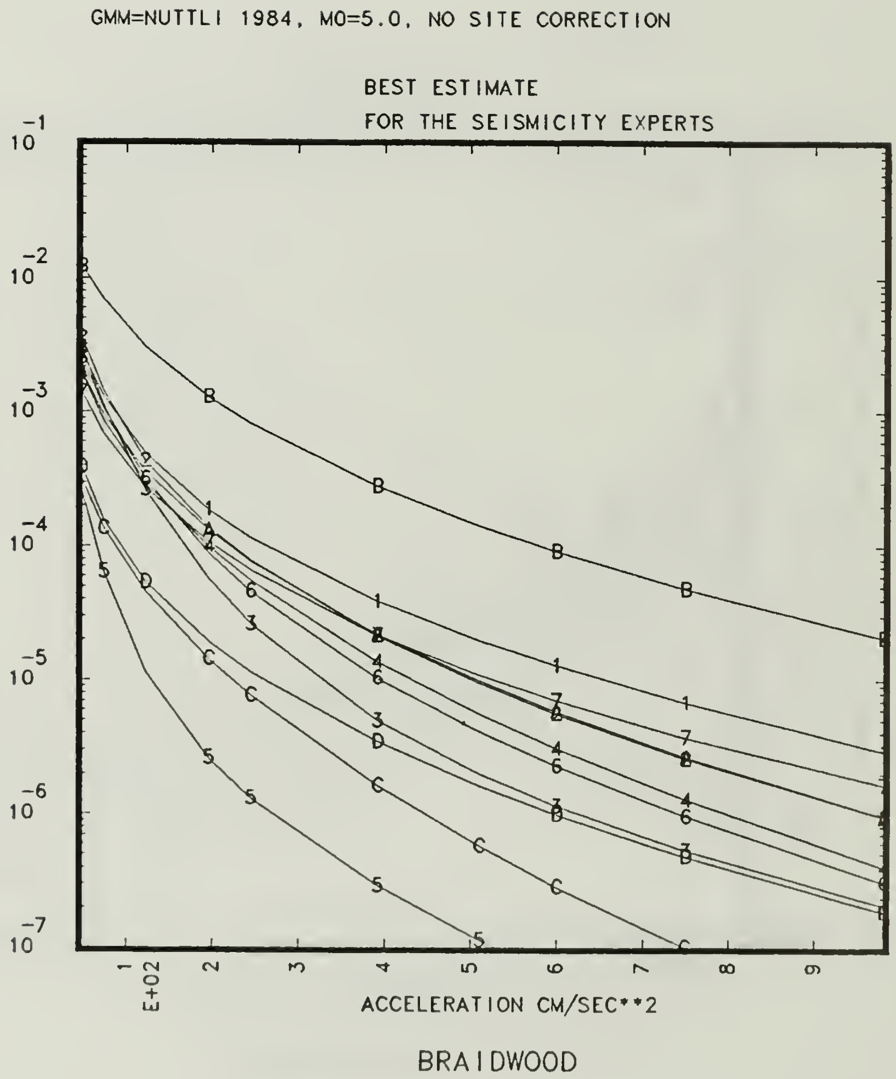


Figure 4.3b BEHCs for PGA for the Braidwood site per S-Expert based on the previous input given in Bernreuter et al. (1985). Only a single PGA model (modified Nuttli) was used.

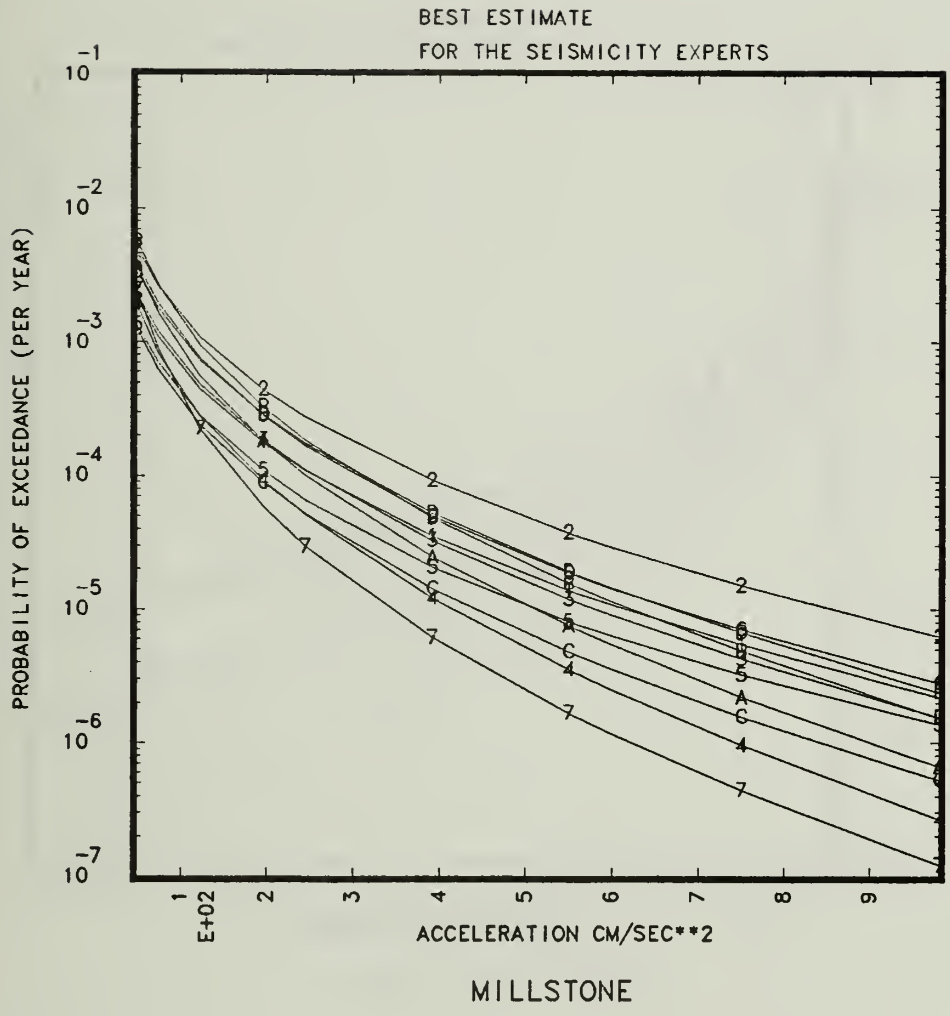


Figure 4.4a BEHCs for PGA for the Millstone site per S-Expert based on the updated input provided by the S-Experts. Only a single PGA model (modified Nuttli) was used.

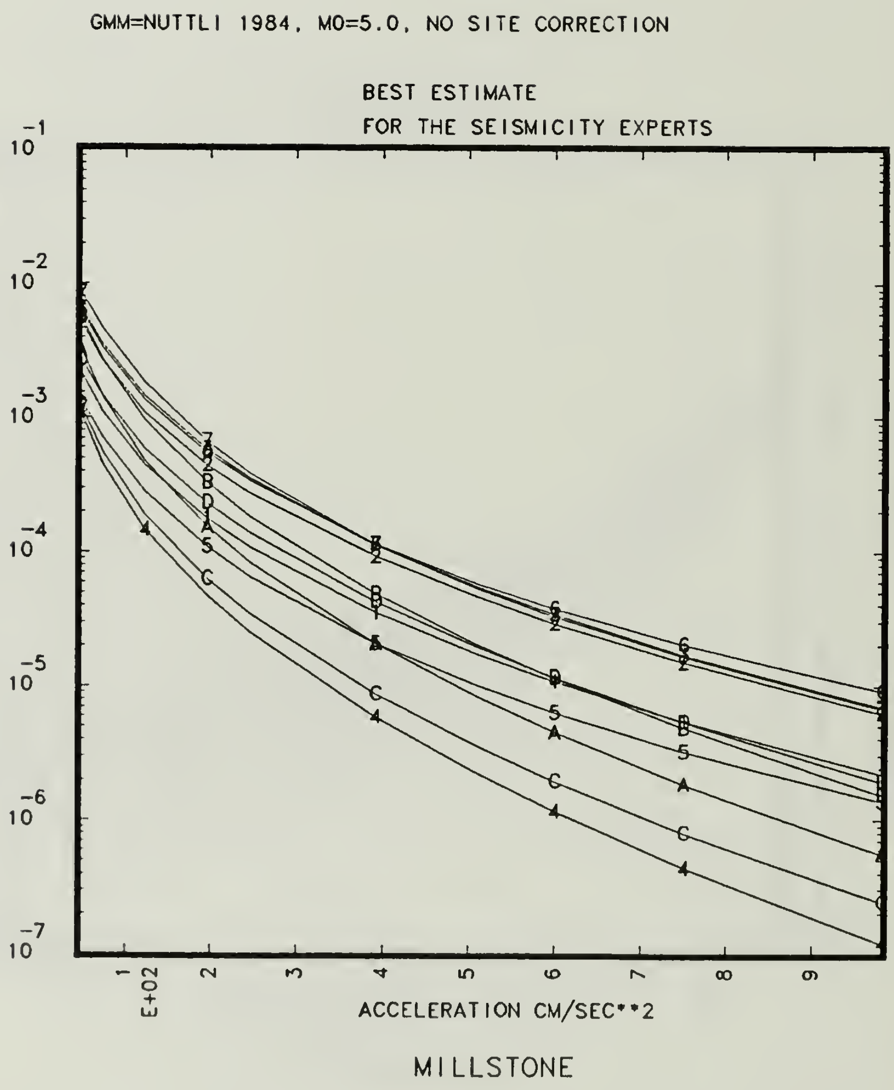


Figure 4.4b BEHCs for PGA for the Millstone site per S-Expert based on the previous input given in Bernreuter et al. (1985). Only a single PGA model (modified Nuttli) was used.

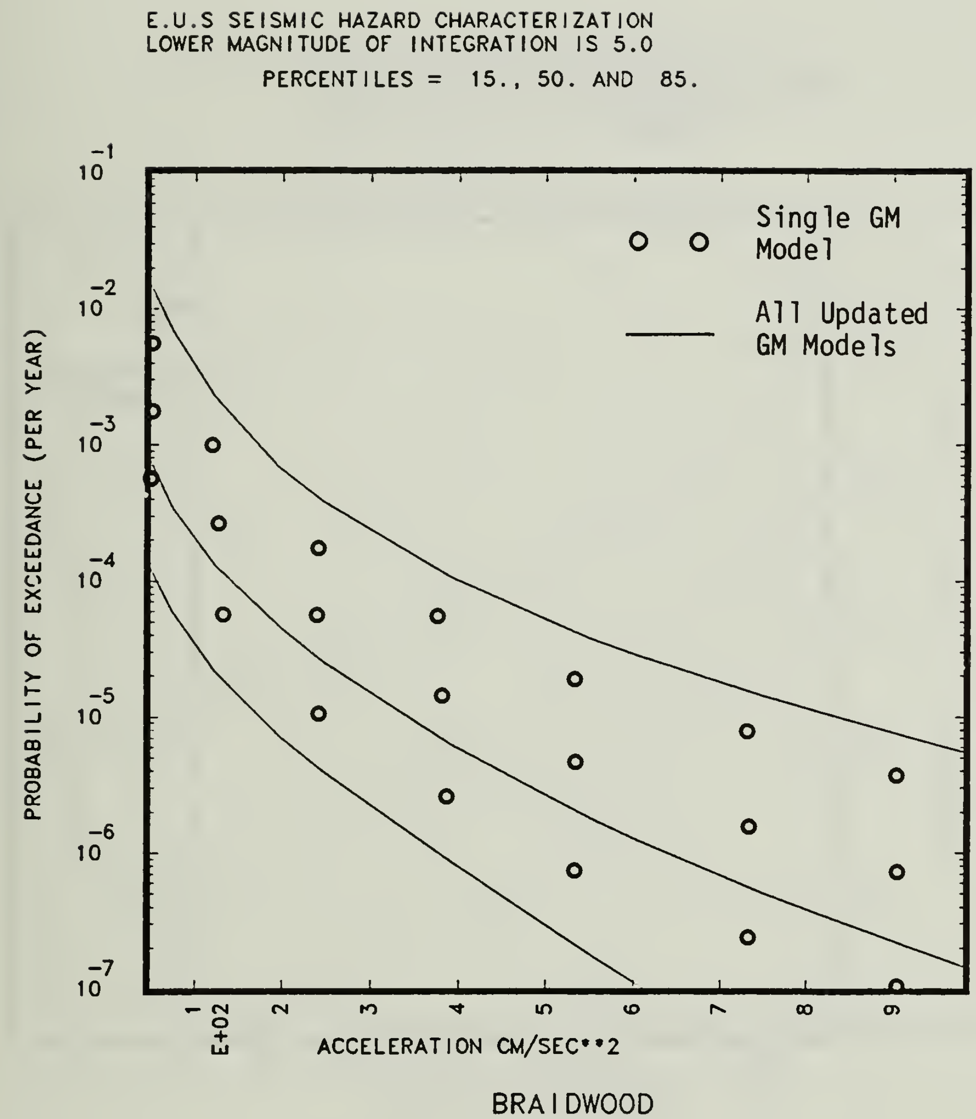


Figure 4.5 Comparison of the 15th, 50th and 85th percentile CPHCs between the CPHCs obtained aggregating over all of the S and G-Experts and the CPHCs obtained using a single PGA model and aggregated over all S-Experts for the Braidwood site.

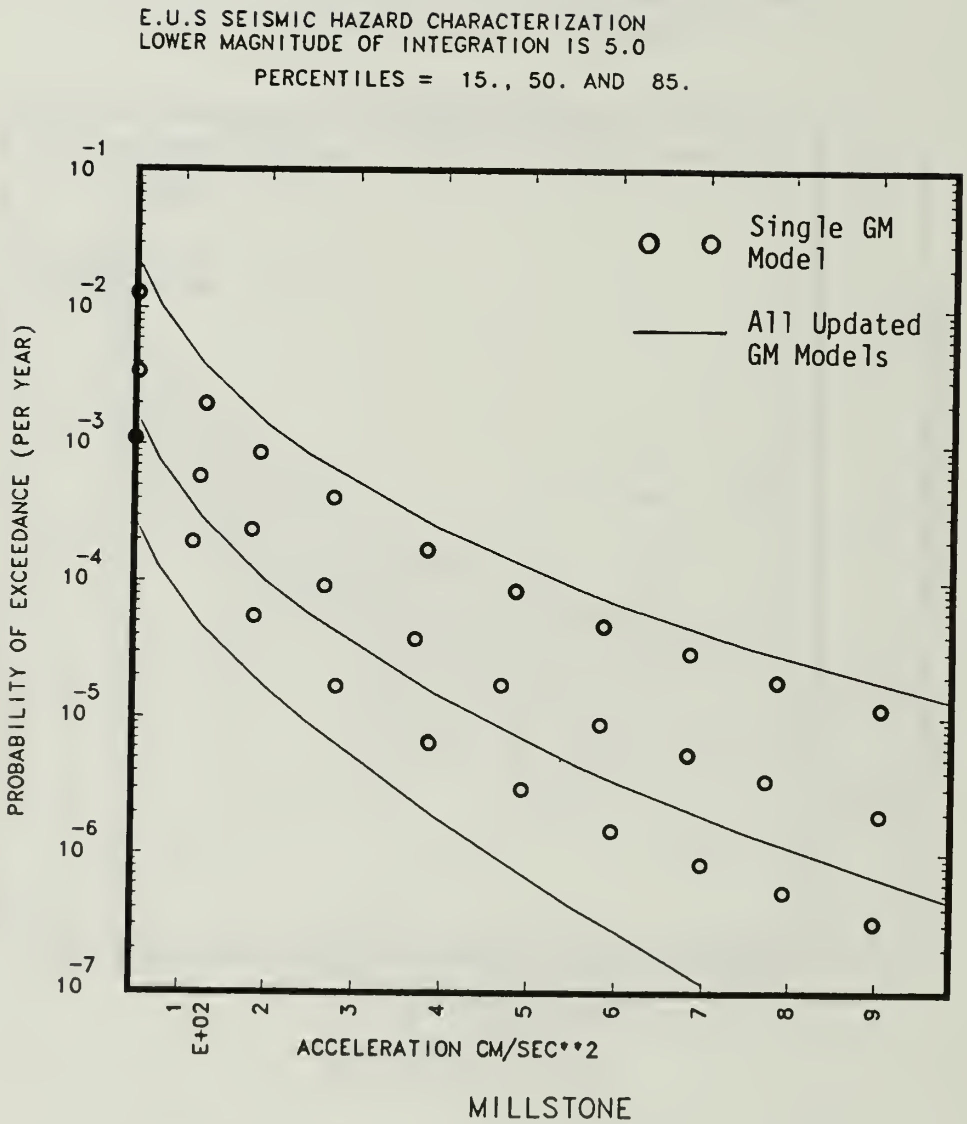


Figure 4.6 Comparison of the 15th, 50th and 85th percentile CPHCs between the CPHCs obtained aggregating over all of the S and G-Experts and the CPHCs obtained using a single PGA model (modified Nuttli) and aggregated over all S-Experts for the Millstone site.

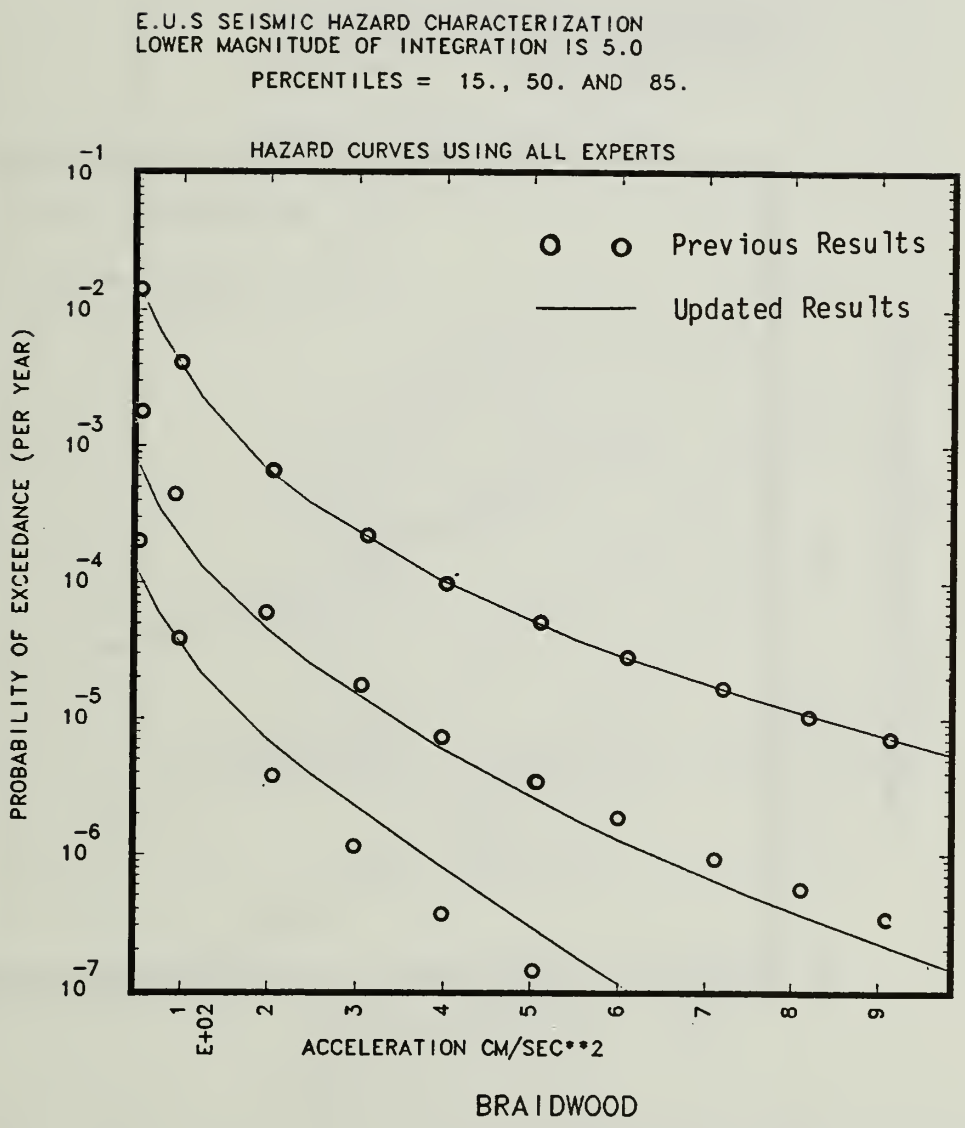


Figure 4.7 Comparison of the 15th, 50th and 85th percentile CPHCs aggregated over all S and G-Experts between the new input and the previous input from the S and G-Experts for the Braidwood site.

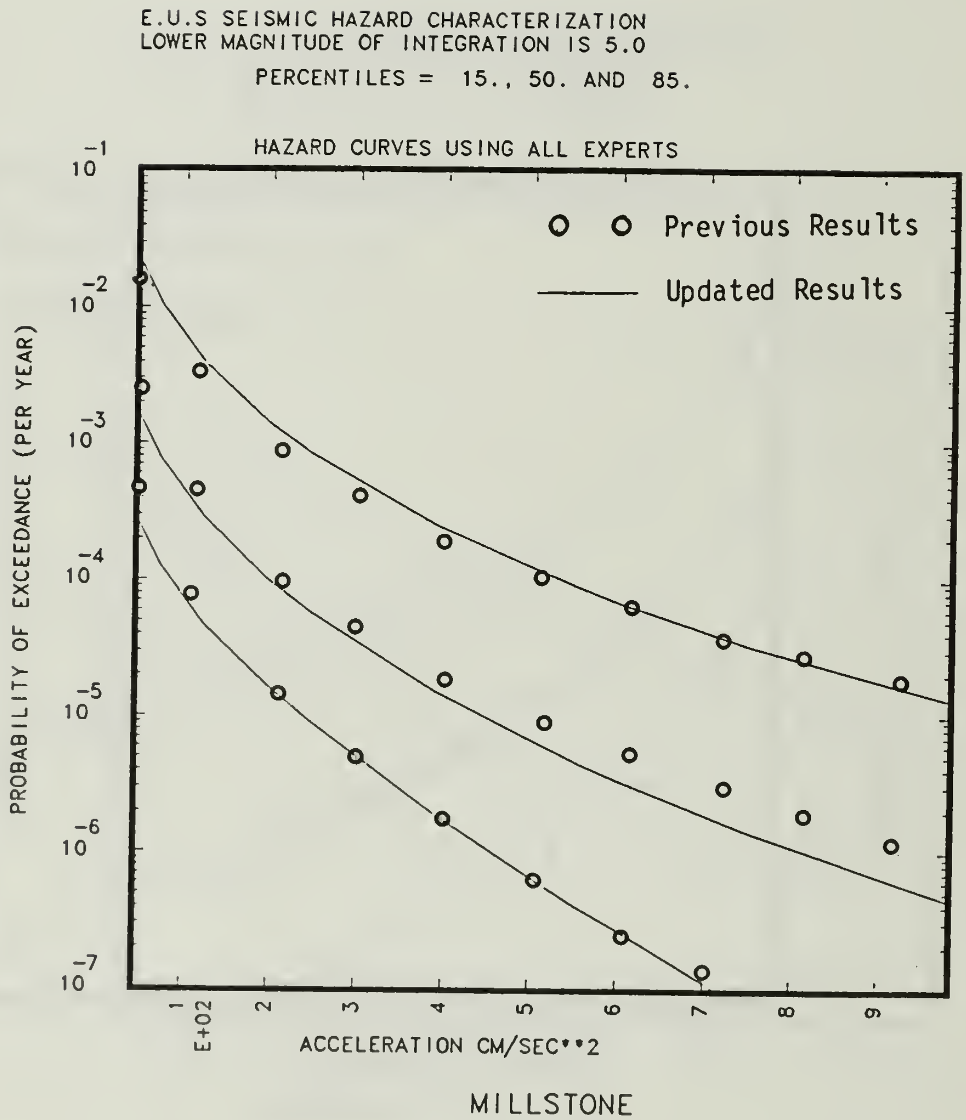


Figure 4.8 Comparison of the 15th, 50th and 85th percentile CPHCs aggregated over all S and G-Experts between the new input and the previous input from the S and G-Experts for the Millstone site.

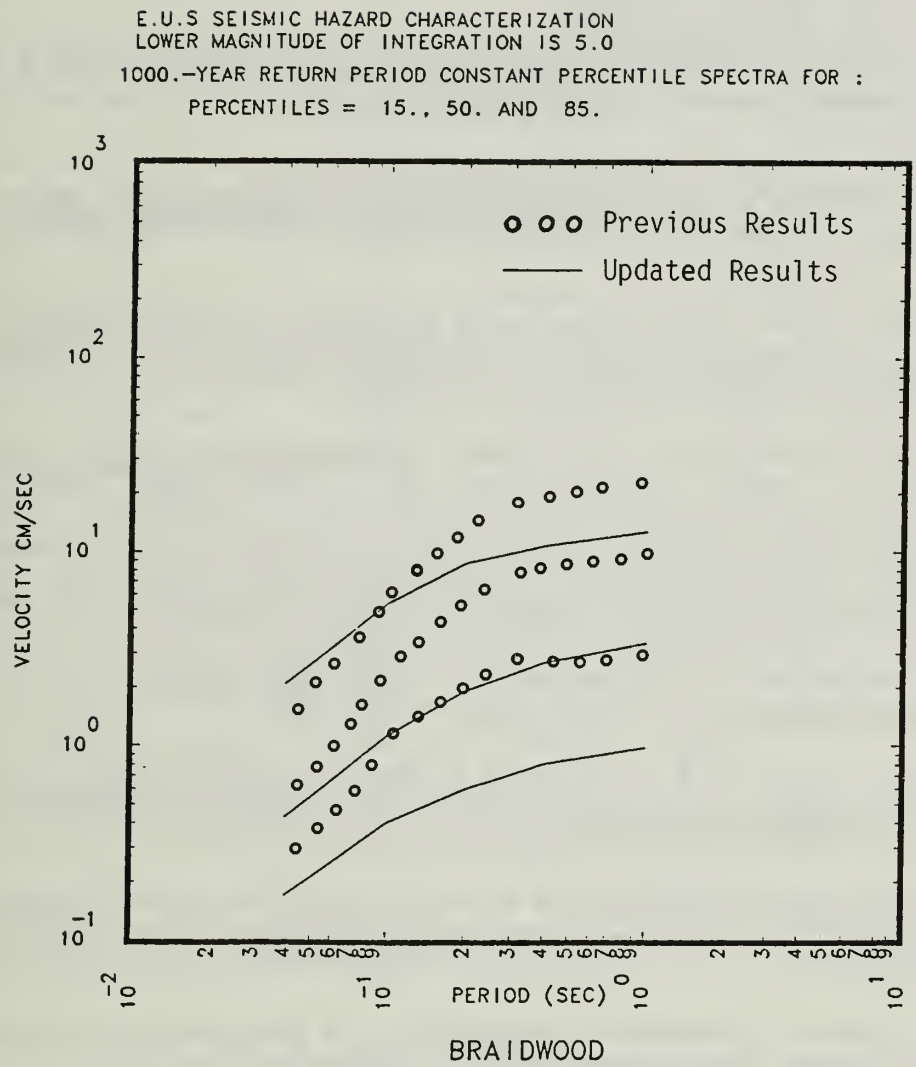


Figure 4.9 Comparison of the 1000 year return period 15th, 50th and 85th percentile CPUHS for 5 percent damping aggregated over all S and G-Experts between the new input and our previous input from the S and G-Experts for the Millstone site.

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APPENDIX A

DOCUMENTATION RESPONSES

A.1 Introduction

Each one of the 11 members of the seismicity panel were asked to document the ways by which they developed their answers to the several questionnaires on zonation and seismicity.

To help them in providing this documentation and to reach a uniform format, we conceived a questionnaire on documentation (Q8), (see Volume VII on questionnaires) in which our philosophy on documentation was presented and specific questions were asked. (See Section 3.4 in this volume for a brief description.)

The purpose of Appendix A is to provide the reader with an unaltered account of the available experts' answers to Q8, to summarize their answers.

A.2 Responses of the S-Experts to Questionnaire Q8

SEISMICITY INPUT DOCUMENTATION FOR EXPERT 1

QUESTION 1 **Discuss briefly the adequacy of the principal sources of information, including physical characteristics and observational data, as a basis for identifying source zones.**

Data for eastern North America are inadequate, which makes the problem of estimating seismic hazard challenging and subject to diverse interpretation.

Except for the New Madrid region, and possibly the Charleston and St. Lawrence Valley regions, the active faults are unknown. None of the active faults of eastern North America, except the Meers fault in Oklahoma (which in historic times has been inactive), show surface rupture.

The generally low rate of seismic activity, together with the relatively short history of earthquakes makes it difficult to define boundaries of seismic zones and to estimate recurrence rates for the zones.

There are only a very limited number of focal mechanism solutions available for eastern North America. When available, they are useful in associating the earthquake with geologic structures. They also are useful for determining the regional stress field.

QUESTION 2 **Outline your principal bases for identifying zones? To what extent did you rely on tectonic and geophysical features as a source of zonation? What, if any, historical seismicity and other observational data did you consider in your development of seismic source zones?**

First, I prepared a map of epicenters of earthquakes of $m_b \geq 4.5$. My choice of this value is based on the following reasoning: Most seismic source zones have a _b_ value of approximately one, and a history of at least 100 years. Therefore the existence of $m_b = 4.5$ earthquakes in 100 years would suggest the occurrence of $m_b = 5.5$ earthquakes in 1000 years. On the other hand, the lack of $m_b \geq 4.5$ earthquakes in 100 years would suggest the lack of $m_b \geq 5.5$ earthquakes in the last 1000 years.

Second, I used basement structure to outline the boundaries of the areas containing earthquakes of $m_b \geq 4.5$. High priority was given to rift zones, next to suture zones (e.g, Appalachian, and Ouachita Wichita Mountains), third to basement uplifts (e.g., Cincinnati Arch, Nemaha uplift) and finally to basement basins or subsidence zones (e.g, Illinois Basin).

Third, I looked at the recurrence rates for these seismic zones. If they did not indicate a seismicity rate different from the background areas, I put them in the background zone.

QUESTION 3 **Identify some of the factors, such as scaling, lower bound magnitude, which influenced your development of the EUS zonation maps. Rank the relative importance of each of these factors, and, if possible, explain how these factors influenced your choice.**

In order of importance,

1. Existence of earthquakes of $m_b \geq 4.5$
2. Existence of basement geologic structures
3. _a_ and _b_ values

My answer to Question 2 attempted to explain how these factors influenced my choice.

QUESTION 4 **Describe, briefly, the influence of, and your use of, these features in the development of your zonation maps.**

I believe that I answered this in my response to Question 2.

QUESTION 5 **Did you feel that these two ways of describing uncertainty provided you with adequate means of expressing your state of knowledge regarding zonation of the EUS? Discuss the types of uncertainties you had identified and attempted to model by specifying a probability of "existence" of a zone and/or alternative zone boundaries.**

My answer to the first of these questions is "yes". In some cases the distribution of earthquakes of $m_b \geq 4.5$ could be associated with different basement structures. That is, alternate boundaries could be drawn, each of which could be related to particular geologic structures. The probability assessment was an expression of my confidence in a particular zone (and its corresponding geologic structure) as being the correct explanation of the earthquake activity.

QUESTION 6 **Discuss briefly what type of uncertainties you considered when specifying the bounds for the seismicity parameters.**

All recurrence curves must depart from linearity and bend down at some magnitude. In attempting to estimate maximum magnitude for a region, the question becomes: Do all recurrence curves bend down at the same magnitude (say m_b = 7.5, an upper limit for global earthquake data) or does the bending down occur at different m_b values in different source zones? If the answer is that all bend down at a particular m_b value, then that value should be the maximum for all source zones. If, on the other hand, they vary by source zones, as I believe they do, then the maximum m_b must be estimated for each source zone. To do so I extended the recurrence curve linearly for a 1000 year return period and used that m_b value as the estimated maximum magnitude.

QUESTION 7 Outline, briefly, the sources of information which formed the basis for your predictions of the largest magnitude.

Lack of knowledge of active faults, and their rupture lengths, prevents us from estimating maximum magnitude on this basis. Also, on the basis of the known lengths of the segments of the New Madrid fault and of the estimated magnitudes of the 1811-1812 earthquakes, I believe the scaling relations, or the relations between surface length and m_b (or M_o), are different for eastern North America than for plate-margin regions.

In my answer to question 6, I attempted to explain my source of information used in predicting the largest magnitude. I forgot to mention that, in constructing the recurrence curve, the area of the source zone must be equalized to some value, the choice of which is rather arbitrary.

QUESTION 8 Did you follow a consistent procedure for predicting M_U? If so, briefly outline the procedure. Were you influenced by any constraints, e.g., limits of measurements scale, when considering your estimate?

I did follow a consistent procedure, which is described in my reply to Question 6. My only constraint was an upper limit on the m_b value, which I believe I took to be m = 7.5.

QUESTION 9 **What are the primary sources of uncertainty that you were trying to describe in determining the upper and lower limits for M_U?**

Uncertainty in the recurrence curve, i.e., in the b and a values.

QUESTION 10 **Discuss, briefly, the various issues, e.g., clusters, catalog incompleteness, related to using recorded earthquake data as a basis for estimating the seismicity parameters (a,b).**

For seismic source zones that have an adequate amount of data, clustering is no big problem. When I encountered an obvious cluster, I tried to estimate the energy released in the cluster, and then replaced the cluster with one earthquake of m_b corresponding to the total energy released. (I also used this method for the 1811-1812 New Madrid earthquakes).

Catalog incompleteness must be compensated for. I used a relatively simple technique, as contrasted with some of those developed in the EPRI study.

I believe that aftershocks should be deleted when the recurrence relation is to be determined.

QUESTION 11 **Outline, and rank, the principal sources, e.g., analysis based on your chosen catalog, the results of the LLNL "uniform approach", you used to develop your estimates of (a,b).**

I used the LLNL catalog except for the central United States, where I used my catalog contained in NUREG/CR-1577.

I used a relatively simple procedure to convert for incompleteness. For a given source zone, I divided the catalog into equal time intervals (e.g, 10 or 25 years and counted the number of earthquakes in a certain magnitude range (e.g., 3.25 to 3.75). When these data are placed in tabular form the time earlier than which the catalog is incomplete for a specific magnitude interval is fairly well defined.

I also used the fact that in populated areas an earthquake exceeding a certain magnitude was bound to be observed and reported upon, considering the large area of perceptibility of eastern North America earthquakes due to low crustal attenuation.

QUESTION 12 If you used a catalog of recorded events as a basis for estimating (a,b), to what extent did you use analytical procedures to adjust for the aftershocks, etc and for incompleteness? Give a brief description of these procedures.

My method of estimating the duration of aftershock activity is subjective. Earthquakes of m_b = 7.5 (e.g, 1811-1812 New Madrid) have an aftershock interval of about 10 years, those of m_b = 6 an interval of about one year and those of m_b = 4 an interval of about one month.

Unless one claims that all earthquake activity between large earthquakes are aftershocks of the earlier large quakes, I don't believe that aftershocks are that much of a problem in estimating a and b values.

QUESTION 13 Identify and discuss, briefly, some of the significant issues impacting characterization of the seismicity of the EUS.

One important question is whether certain areas which have not displayed much seismic activity in historic times might in the near future produce a large earthquake. The Meers fault is a good example. Another is the great China earthquake of 1556 that killed over 800,000 people, but in recent times dosen't even show much microseismic activity. If this is a true or real problem in the EUS, then the concept of a seismic budget, and the meaningfulness of _a_ values, must be abandoned. It would make all our attempts to estimate seismic hazard meaningless.

If we could accurately determine focal depth of micro-earthquakes and the occasionally larger earthquakes that occur, I believe we could use this information to estimate maximum magnitude events for a region. Only the regions that have earthquakes of depth, greater than, say, 10 km would have the potential for producing a very large earthquake.

QUESTION 14 What do you consider to be the major sources of uncertainty in predicting the seismicity parameters (a,b)?

1. Low rate of seismic activity
2. The historic record may be too short (see my reply in Question 13).
3. Poor determination of earthquake magnitudes as given in the catalogs. I believe this may be a problem in northeastern U.S. and possibly in southwestern Canada.
4. Incorrect identification of source zone boundaries.

QUESTION 15 Were the alternates presented in the seismicity questionnaires for modeling potential correlation between (a,b) adequate for you to express your views about your joint uncertainty about the seismicity parameters? Discuss your views on correlation between a and b.

I am not convinced that there is a correlation between a and b values. The b value should depend on the state of stress and strength of friction on the fault surface. Although the friction may depend upon frequency of movement. I don't believe the state and stress does.

SEISMICITY INPUT DOCUMENTATION FOR EXPERT 3
QUESTIONNAIRE Q8

QUESTION 1 **Discuss briefly the adequacy of the principal sources of information, including physical characteristics and observational data, as a basis for identifying source zones.**

(1) Historical Seismicity (spatial and temporal) record

a. Too short to show any long term cycles or changes on the order of millenia.

b. Long enough to show overall general stationarity between non-instrumental data (centuries) and network data (decade). Those variations seen are probably expectable dispersions about the longer term mean rates.

c. Maximum events, e.g. those at New Madrid and Charleston, with repeat time from seismicity and geology data that are several times the historical record have fortuitously occurred in a few places in the region. What surprises are waiting elsewhere is unknown. This impacts maximum magnitude estimate.

(2) Paleoseismicity data at New Madrid and at Charleston have given estimates of return periods that were roughly comparable to those derived by historical earthquake frequency plus documented the repetitive nature of those source zones along with their stationarity in terms of millenia. Mitigates somewhat the deficiency of the historical seismicity record.

(3) Geological Data- Bedrock geological maps entirely adequate. Sub surface control generally inadequate (Depth dimension missing, especially at basement depths).

(4) Potential Field Data (gravity + magnetic) generally adequate.

(5) Reflection Seismic data skimpy and of highly variable coverage, but most useful for 3D information (impacts (3) above).

(6) Ditto for Stress data.

QUESTION 2 Outline your principal bases for identifying zones? To what extent did you rely on tectonic and geophysical features as a source of zonation? What, if any, historical seismicity and other observational data did you consider in your development of seismic source zones?

(1) Historical Seismicity used as primary baseline factor
Spatial: Lineations, clusters, diffuse distributions, virtually Aseismic.
Energy Level: Historical maximum, general level over time with respect to surroundings
Frequency: Persistence over time. Sporadic or continuous?

(2) Regional Geology Provincial structure approach, i.e., large scale (100's km) architecture used to modify boundaries of historical seismicity to develop seismotectonic provinces (zones); tectonic history including accreted terranes postulates used in same manner.

(3) Regional Gravity and Magnitude Data - Used only slightly in an "anomaly pattern" type of approach.

(4) Local Data (in the order of tens of kilometers) used explicitly whenever available in an attempt to infer where else in one surrounding region similar structures might be reasonably expected. Geology, Reflexion Seismology, Paleoseismicity.

(5) Vertical Distribution of Seismicity (focal depths)- important to define thickness of brittle, seismogenic upper crustal layer.

QUESTION 3 Identify some of the factors, such as scaling, lower bound magnitude, which influenced your development of the EUS zonation maps. Rank the relative importance of each of these factors, and, if possible, explain how these factors influenced your choice.

(1) Size of Zones Except for the three locales in the EUS that have probably had their maximum earthquake (New Madrid, Charleston, St. Lawrence Valley). The zones should be relatively large (100's km) in size because of lack of knowledge to be more detailed and because of a given geologic province containing a family of "similar" structures as candidates for strain accumulation. Encompass uniform historical seismicity and similar regional geology.

(2) Shape of Zones - Should conform to the regional geologic and tectonic "grain" or "fabric" because of last reason given in (1) above. Encompass "uniform" historical seismicity.

The above comments are of equal importance.

QUESTION 4 Describe, briefly, the influence of, and your use of, these features in the development of your zonation maps.

Because of "regional size" approach, felt no need for "complementary" zones".

"Complementary zone" was defined as that region without any identifiable character or temporal persistence in the historical seismicity record and association with a regional geologic province that had such characteristics.

QUESTION 5 **Did you feel that these two ways of describing uncertainty provided you with adequate means of expressing your state of knowledge regarding zonation of the EUS? Discuss the types of uncertainties you had identified and attempted to model by specifying a probability of "existence" of a zone and/or alternative zone boundaries.**

Yes

Types of uncertainty-

a. Spatial extent and configuration of zones

b. Location of boundaries between adjacent zones, i.e., the "change" from one seismic habit to a different one.

QUESTION 6 **Discuss briefly what type of uncertainties you considered when specifying the bounds for the seismicity parameters.**

Length and completeness of historical record

Size of geologic host province and activity in adjacent provinces and in similar provinces elsewhere in world. Amount of detailed studies (network/aftershock monitoring, reflexion seismology, deep bore holes, etc)

Occurrence/non occurrence of maximum magnitude event.

QUESTION 7 **What does the terminology "95 percent confidence or uncertainty bounds" mean to you? How did you interpret it?**

In repeated trials or calculations, 95% of the bounds will contain the true value.

QUESTION 8 **Discuss, briefly, the significant issues related to predicting the largest magnitude earthquake that can be expected to occur in a source zone.**

The absolute size of historical maximum is one of the significant issues with respect to predicting maximum magnitude size of historical maximum with respect to size of geologic structure. Another issue is the tectonic history of the area, probable repeated reactivations, horizontal and vertical extent of past tectonic episodes, etc. Orientation of candidate geologic structures with respect to the contemporary East North easternly compressive stress field.

Also the thickness of the brittle failure, seismogenic layers; maximum focal depths observed, and the size of probable fault "planes" from network and/or aftershock monitoring.

QUESTION 9 **Outline, briefly, the sources of information which formed the basis for your predictions of the largest magnitude.**

See Q8 above.

QUESTION 10 **Did you follow a consistent procedure for predicting M_U? If so, briefly outline the procedure. Were you influenced by any constraints, e.g., limits of measurements scale, when considering your estimate?**

No

Outline of procedure used:

(1) Define background earthquake as m_b = 5 1/2

(2) Determine historical maximum; size and character of spatial seismicity pattern; size and character of associated geology, geophysics reflexion seismlogy features.

(3) Judge compatibility of elements in (2).

(4) If compatible, use historical maximum as M_U. If not, adjust upward until compatibility is achieved.

QUESTION 11 **What are the primary sources of uncertainty that you were trying to describe in determining the upper and lower limits for M_U?**

Very subjective, no real basis for procedure except for departure from compatibility constraints (Q10) by allowing greater than average slip on smaller faults and less slip than average on larger faults.

QUESTION 12 **Discuss, briefly, the various issues, e.g., clusters, catalog incompleteness, related to using recorded earthquake data as a basis for estimating the seismicity parameters (a,b).**

(1) Removal of Foreshocks and Aftershocks: Generally clear enough that subjective removal is adequate. Statistical/analytical methods can be employed but it is problematical if they can do a significantly better job. In EUS, the number of significant sequences is small enough that any errors related to their removal should be insignificant without other errors present.

(2) Variations in detection, location and sizing thresholds with time due to population levels and numbers of seismographs.
A serious problem with no real effective solutions available; mitigated somewhat by combining historical data on larger earthquakes with network data on smaller shocks properly.

(3) Variations due to societal conditions, Civil War in South; lack of settlement west of St. Louis in the 18th and early 19th centuries.

(4) Short length of record with respect to repeat times for larger shocks. Implies larger events missed in some/many areas?

QUESTION 13 **Outline, and rank, the principal sources, e.g., analysis based on your chosen catalog, the results of the LLNL "uniform approach", you used to develop your estimates of (a,b).**

LLNL uniform approach. Rank as well as any other approach for a large area/volume of data. That is, short of doing an exhaustive, special study for each zone.

QUESTION 14 **If you used a catalog recorded events as a basis for estimating (a,b), to what extent did you use analytical procedures to adjust for the aftershocks, etc and for incompleteness? Give a brief description of there procedures.**

Procedure for adjustment aftershocks and incompleteness. As discussed earlier, none, except to subjectively delete lower magnitudes that depart from the straight line formed by the larger magnitudes.

QUESTION 15 **Identify and discuss, briefly, some of the significant issues impacting characterization of the seismcity of the EUS.**

Issues on log N = a-bM in EUS.

(1) Range of linear semi-log relationship
Worldwide and regional EUS data indicate OK from smallest magnitude to somewhere in the upper magnitude range. Just where and how the departure from linearity occurs is a major problem. Constraints available are the characteristic earthquake model for individual fault zones and then for a multiplicity of fault zones, and the presence of a limiting size/stress level of individual seismogenic structures based on their geometric and mechanical characteristics. No clear cut choice among available techniques.

(2) Method of departure from lineary at the larger magnitudes. Same as (1) above

(3) Short historical record, sparse data base, long return periods (Paleoseismicity)

(4) Subject to significant short term temporal variations in the long term average rate implied by long N - a-bM. Results in spatial variations also.

(5) Not enough Paleoseismicity data for independent estimate of return periods for larger shocks.

(6) Should be 1.0 $\pm$ 0.2

(7) Can vary from zone to zone because of different populations of seismogenic structures

QUESTION 16 What do you consider to be the major sources of uncertainty in predicting the seismicity parameters (a,b)?

(1) b easier to predict reliably
(2) a more difficult because tied to definition of study volume, length of time considered and lower magnitude cutoff chosen, focal depth distribution.
(3) a and b are independent parameters but are usually not treated that way.
(4) Choosing M_L and M_U levels for a given catalog.
(5) Definition of time period to be employed in the determination of log N = a-bM.

QUESTION 17 Were the alternates presented in the seismicity questionnaires for modeling potential correlation between (a,b) adequate for you to express your views about your joint uncertainty about the seismicity parameters? Discuss your views on correlation between a and b.

Yes Discussed previously.

SEISMICITY INPUT DOCUMENTATION FOR EXPERT 5
QUESTIONNAIRE Q8

QUESTION 1 **Discuss briefly the adequacy of the principal sources of information, including physical characteristics and observational data, as a basis for identifying source zones.**

The principal sources of information which were used for zonation were

1. maps of historical and recent instrumental epicenters
2. tectonic maps of North America
3. energy release maps for the Eastern United States

In addition, in specific areas, geologic maps and stress orientation maps as well as geophysical information were utilized.

Treating the adequacy of the principal sources of information -

1. The historic maps of epicenters suffer the lack of accurate information as to exact location and size. Of equal importance is the lack of any information on depth of occurrence. The recent instrumental results are useful because of their accuracy for (mostly) small magnitude events. The general correspondence of the recent and historical data in map view is encouraging but the comparison of these two data sources strongly suggested spatial non-stationarity in the data.

2. Tectonic maps were adequate to define uniform geological characteristics but, some known details were not included and of course, data on more recently documented features such as the Meers Fault had to be obtained from additional sources.

3. Energy release maps are simply derived from observed historic and recent seismicity and subject to all the inadequacies noted above.

QUESTION 2 **Outline your principal bases for identifying zones? To what extent did you rely on tectonic and geophysical features as a source of zonation? What, if any, historical seismicity and other observational data did you consider in your development of seismic source zones?**

The principal bases for zonation were listed in Question 1.

In the mid-west, excluding the New Madrid area, equal emphasis was placed on geophysical and mapped tectonic features and on the historical recent instrumental seismicity. In the New Madrid zone, all possible sources (and they are extensive) were used to define the zone. In the Eastern United States, major emphasis was placed on the seismicity although geologic maps were used as appropriate.

It should be noted that the alternative model that I proposed involving a single zone along the Atlantic seaboard was based both on the seismicity patterns and on the stress patterns. Future work may change my estimate of the correctness of that alternative model.

QUESTION 3 **Identify some of the factors, such as scaling, lower bound magnitude, which influenced your development of the EUS zonation maps. Rank the relative importance of each of these factors, and, if possible, explain how these factors influenced your choice.**

I have always felt that the size of the zone in any seismic zonation process must be a direct reflection of the amount of information available to the zoner and the degree of certainty of the zoner in the results. An extremely large number of small zones in the Eastern United States are not justified by the totality of currently available data. In fact, the alternative model that I proposed suggests the nature of both the uncertainty and the information available. Given the uncertainty in all the observational data (particularly the locations and sizes of seismicity, and the data-cutoffs, the zonation has to be broad. Certainly, none of the zonation maps by any of the experts can be considered to be more than an educated guess until we understand the causative mechanisms of intraplate seismicity. Given the lack of this understanding, zonation, in my mind, must be general and subject to the caveat that it is incorrect. The hope (and it should be clearly identified as such) is that the totality of the expert zonation will bracket the uncertainty in zonation. The increasing evidence for non-stationarity of occurrence may invalidate that hope.

Different factors affected my advice of zones in different areas but the most important factor was the amount of information available. Although lower magnitude cutoff played a role, it was not a primary one except where a "characteristic" earthquake on a particular geologic feature entered into the zonation.

QUESTION 4 Describe, briefly, the influence of, and your use of, these features in the development of your zonation maps.

See Question 3.

QUESTION 5 Did you feel that these two ways of describing uncertainty provided you with adequate means of expressing your state of knowledge regarding zonation of the EUS? Discuss the types of

uncertainties you had identified and attempted to model by specifying a probability of "existence" of a zone and/or alternative zone boundaries.

The two ways of describing uncertainty provided adequate means of expressing my state of knowledge regarding zonation of the Eastern United States. All of the uncertainties discussed earlier entered in my decisions regarding zonation particularly the alternative zones. Certainly, the alternative zone may prove to be the 'correct' one and, if so, its probability of existence would be (and, of course may now be) 100%.

QUESTION 6 Discuss briefly what type of uncertainties you considered when specifying the bounds for the seismicity parameters.

Uncertainties considered included:

1. Uncertainties in historic and recent (instrumental) data base particularly intensities and/or magnitudes.

2. Knowledge unknowns - particularly lack of knowledge of the causative mechanisms - e.g., if you don't know what causes these events, how can you assign an upper magnitude limit?

3. Uncertainty in extrapolating seismicity parameters to larger than observed and low magnitudes.

QUESTION 7 What does the terminology "95 percent confidence or uncertainty bounds" mean to you? How did you interpret it?

Assuming a Gaussian or bell shaped curve centered on the 'best estimate' value, the true value will lie within ±2s of the 'best estimate' value.

QUESTION 8 **Discuss, briefly, the significant issues related to predicting the largest magnitude earthquake that can be expected to occur in a source zone.**

There are several significant issues related to predicting the upper magnitude cutoff.

1. Is there an upper magnitude cutoff?

2. The limitations of the historic record particularly its limited duration relative to postulated return periods.

3. The applicability of the 'characteristic' earthquake model in the Eastern United States.

4. Numerous others.

QUESTION 9 **Outline, briefly, the sources of information which formed the basis for your predictions of the largest magnitude.**

Sources used in the prediction of the upper magnitude included the following:

1. seismicity parameter plots based on the historic catalog and recent instrumental data - used independently

2. geologic and geophysical data (and tectonic interpretations)

3. physical constraints

QUESTION 10 **Did you follow a consistent procedure for predicting M_U? If so, briefly outline the procedure. Were you influenced by any constraints, e.g., limits of measurements scale, when considering your estimate?**

The prediction of the upper magnitude cutoff involved the following procedure:

1. Select an initial M_u based on plots of historic and recent instrumental seismicity (where available). A usual starting value was one intensity unit greater than that observed to date in the historic record.

2. Modify the initial value based on geologic and geophysical inputs such as known fault characteristics (where available), 'characteristic' earthquake limits etc.

3. Modify for any effects of physical constraints. Among others, I am convinced that most regions are capable of producing an intensity VI event so that, in effect set a lower limit to I_u.

QUESTION 11 **What are the primary sources of uncertainty that you were trying to describe in determining the upper and lower limits for M_U?**

The primary source of uncertainty that was described by the selection of the upper and lower bounds of M_u (or I_u) was whether such an entity existed.

QUESTION 12 **Discuss, briefly, the various issues, e.g., clusters, catalog incompleteness, related to using recorded earthquake data as a basis for estimating the seismicity parameters (a,b).**

Ideally, to estimate seismicity parameters, one should have both a 'perfect' catalog, i.e., one which has exact locations, sizes, etc., and a 'complete' catalog, i.e., one with uniform size coverage as a function of time. The best catalogs are, of course, poor approximations to these ideal catalogs.

Issues affecting the choice of seismicity parameters are:

1. present catalogs have large uncertainty and errors in location and size

2. present catalogs are incomplete at different size levels at different points in time.

3. present catalogs normally include aftershocks, ice-quakes, etc., which probably should not be included in choosing seismicity parameters.

QUESTION 13 Outline, and rank, the principal sources, e.g., analysis based on your chosen catalog, the results of the LLNL "uniform approach", you used to develop your estimates of (a,b).

Analysis of modified catalog entries was used exclusively as the basis of assigning a and b values.

QUESTION 14 If you used a catalog recorded events as a basis for estimating (a,b), to what extent did you use analytical procedures to adjust for the aftershocks, etc and for incompleteness? Give a brief description of these procedures.

Starting with a modified catalog (based on our own catalog), the following simple procedures were used:

1. Aftershocks (greater than I_0 IV) were removed if they occurred within a one year period following an I_0 = VII or greater event.

2. Only events in the range I_0 = IV and above were used in the analysis.

3. Where known incompleteness was assumed at I_0 IV, those data were disregarded in the analysis. The same procedure was used at higher intensities in earlier times.

QUESTION 15 **Identify and discuss, briefly, some of the significant issues impacting characterization of the seismicity of the EUS.**

The most significant issues that impact characterization of the seismicity of the Eastern United States are:

1. the lack of knowledge of the causative mechanisms of the seismicity

2. the lack of an adequate catalog

3. the lack of knowledge of 'correct' zonation, i.e., which events should be included in the analysis

QUESTION 16 **What do you consider to be the major sources of uncertainty in predicting the seismicity parameters (a,b)?**

The major sources of uncertainty in predicting seismicity parameters are:

1. the historic (and recent) data uncertainties

correct location
correct size
incompleteness of the data set

2. the possible non-stationarity of the seismicity, i.e., the Meers Fault question, eastern Massachusetts, etc.

3. the uncertainty in zonation

QUESTION 17 Were the alternates presented in the seismicity questionnaires for modeling potential correlation between (a,b) adequate for you to express your views about your joint uncertainty about the seismicity parameters? Discuss your views on correlation between a and b.

The alternatives presented in the seismicity questionnaires for modeling potential correlation between (a,b) were adequate to express my views of the joint uncertainty about the seismicity parameters. My views on the correlation are simply that a and b are independent parameters.

In the final analysis, empirical judgements or 'educated guesses' are used to derive these parameters. Until the causative mechanisms of these intraplate events are known, all derived seismicity zonation and parameters no matter how involved with detailed mathematical analyses, will remain 'best estimates'.

SEISMICITY INPUT DOCUMENTATION FOR EXPERT 6
QUESTIONNAIRE Q8

QUESTION 1 **Discuss briefly the adequacy of the principal sources of information, including physical characteristics and observational data, as a basis for identifying source zones.**

I think that the observed seismicity is the only really viable source of information for identifying source zones in most (if not all) of the eastern United States (EUS). In principle, physical characteristics should be the most important source of information. However, so little is known about the cause of earthquakes in the EUS that it is hard to say what physical characteristics should be considered as significant for identifying source zones.

Furthermore, the generally accepted hypothesis--that EUS earthquakes occur when the stress locally exceeds the strength of preexisting zones of weakness--doesn't help me very much in identifying source zones. I consider that hypothesis to be true by definition, but I don't know how to apply it. For example, what zones of weakness should I be looking for? How might these zones of weakness be identified from geologic structures that outcrop on the surface or from deeper earth structures inferred from geophysical data? I am not even sure what scale of structures I should be looking for.

The part of the EUS that I am most familiar with is the northeastern region (NEUS), and in that region the identification of specific active features has proven to be quite difficult. Unlike the situation along plate boundaries, it is not at all clear whether faults mapped at the earth's surface in the NEUS are the same faults along which the earthquakes are occurring. I know that I have allowed my familiarity with the NEUS to bias my source zonation of other parts of the EUS, and it is hard for me to avoid that. Although I am not as familiar with earthquake activity in New Madrid, MO area, my sense is that the cause of the earthquakes in that area are better understood. Thus, my zonation of the New Madrid area is more dependent on physical characteristics than are my zonations of other parts of the EUS.

QUESTION 2 **Outline your principal bases for identifying zones? To what extent did you rely on tectonic and geophysical features as a source of zonation? What, if any, historical seismicity and other observational data did you consider in your development of seismic source zones?**

The principal basis for identifying source zones on my seismic zonation maps was locations of historical and instrumentally located epicenters. I compared a number of different maps of seismicity in the EUS, including LLNL and EPRI maps as well as a recent (preliminary) map of seismicity in the U.S. that will eventually be published in one of the Decade of North American Geology volumes. The seismicity maps that I examined were plotted on various different scales and/or using different symbols (e.g., smaller symbols for smaller events).

I had more detailed maps of seismicity and geologic structures available to me for the NEUS. Nonetheless, I tried to make the scale of source zones homogeneous throughout the EUS, unless I had a particular physical reason for characterizing an area on a smaller scale. Thus, my source zones for the NEUS probably have less detail than they might have had if that was the only region I was analyzing, and my zones for other parts of the EUS probably have more detail than they would have had if I was unaware of certain details in the NEUS.

In some cases tectonic and geophysical features were used to define boundaries. In general, however, physical characteristics "took a back seat" in my judgements (see response to Question 1).

QUESTION 3 **Identify some of the factors, such as scaling, lower bound magnitude, which influenced your development of the EUS zonation maps. Rank the relative importance of each of these factors, and, if possible, explain how these factors influenced your choice.**

(1) Scale of Details:

With the exception of a few specific areas (e.g., New Madrid, MO), I have no compelling reason to believe that the scale of source zones should vary across the EUS. Thus, I generally tried to make the scale of source zones homogenous throughout the EUS unless I had specific physical reasons to characterize an area with greater detail. To some extent, I relied on my understanding of the scale of details in areas that I am most familiar with (primarily the NEUS). At the same time, I tried not to overemphasize details in areas that I am more knowledgeable about, because the resulting map would appear to imply an unrealistic distribution of scales of features. To that end, I tried to think of what NEUS would look like to seismologists who study other parts of the world, and from that perspective I tried to zone the rest of the EUS.

I suppose that this approach is inherently biased by what I know about the NEUS, but I couldn't think of any way to avoid that bias.

(2) Lower bound magnitude:

I think that an m_{bLg} 3.75 earthquake could occur just about anywhere in the EUS, but I am not as convinced that an m_{bLg} 5.0 event could occur anywhere in the region. Most likely, that belief influenced my development of zonation maps, but it is hard to say how.

QUESTION 4 **Describe, briefly, the influence of, and your use of, these features in the development of your zonation maps.**

(1) Background:

I was not really clear on the significance of the distinction between background zone (EPRI) and complementary zone (LLNL) described on page 9 of Q7. I guess the idea is that in the case of the background you consider "features", whereas in the case of complimentary zone it is just a matter of "what is left over" after the rest of the zonation map is finished. But, how does that translate into differences in assigned seismicity parameters?

(2) Complementary Zone:

In my zonation maps, the complementary zone is the part of the EUS that was left over after all other zone boundaries were created. I was not very confident in the zone boundaries that I was able to create from the available source of information, so I tried to find a few different ways to compensate for that uncertainty. For example, the maximum magnitude for the complementary zone was large (M_U = 6.0 + 0.5), and I allowed for two alternative maps of zonation. Thus, my zonation and seismicity parameters were intended to allow at least some probability of a damaging earthquake occurring anywhere in the EUS.

Given the currently available information about earthquake activity in the EUS, I did not see any reason for dividing the complementary zone into regional complementary zones.

QUESTION 5 **Did you feel that these two ways of describing uncertainty provided you with adequate means of expressing your state of knowledge regarding zonation of the EUS? Discuss the types of**

uncertainties you had identified and attempted to model by specifying a probability of "existence" of a zone and/or alternative zone boundaries.

These two ways of describing the uncertainty generally seemed adequate, but I think that the way I applied this aspect of the LLNL methodology in my responses to Q7 was a little different from the way it was intended to be applied. During the "one-on-one interview" regarding my responses to this questionnaire (June 25, 1987), I discussed my approach regarding this aspect of the LLNL methodology with J. Savy and D. Bernreuter. At the end of that meeting, it seemed that they were able to incorporate my responses (and what I had intended to model) into the LLNL methodology.

(1) Probability of Existence:

I tried to identify and model the probability that a particular zone was seismically different from the area surrounding it.

(2) Alternative Zone Boundaries:

Original Zonation Map (response to Q1): Given that a zone exists, I tried to identify and model the probability that my best estimate map had the correct boundaries for that zone. My lack of confidence regarding the existence of the zones in that map was accounted for by proposing alternative zone boundaries.

Revised Zonation Map (response to Q7): In my revised zonation map, I used my original best estimate map as an alternative map rather than specifying alternative zones for the revised map. Also, I added a third map which consisted of one "mega-zone" including the entire EUS without internal zonation boundaries. So in this case, I think that what I really submitted was "alternative maps" rather than "alternative zones". My level of confidence values for alternative boundary shapes are, therefore, really level of confidence values for each of the three maps.

QUESTION 6 **Discuss briefly what type of uncertainties you considered when specifying the bounds for the seismicity parameters.**

The uncertainties that I considered when specifying the bounds for the seismicity parameters were:

(1) Incomplete recording in catalogues.

(2) Temporarily and/or spatially varying seismicity parameters.

(3) The possibility that even if we could correct for incomplete recording and if seismicity parameters are stationary within a given zone, we may nonetheless be limited by observations over too short a period of time to see the real, stationary seismicity parameters.

QUESTION 7 **What does the terminology "95 percent confidence or uncertainty bounds" mean to you? How did you interpret it?**

95% Confidence Bounds: For a given parameter, p, there is a probability of 0.95 that the true value for p lies somewhere within the 95% confidence bounds.

Uncertainty Bounds: I interpret this be a more general concept indicating the limits of a range of values that contain the true value of p with some (unspecified) level of confidence.

QUESTION 8 **Discuss, briefly, the significant issues related to predicting the largest magnitude earthquake that can be expected to occur in a source zone.**

In principle, it makes the most sense to use physical characteristics (such as fault length, rupture area, stress drop, etc.) to predict maximum magnitudes for a given source zone. However, I don't think that such information is very useful for most of the EUS, given our present lack of understanding of the cause of EUS earthquakes. As in the case of other parameters, I relied heavily on the observed record of seismicity in estimating maximum magnitudes.

Again, I consider the New Madrid, MO area to be an exception to this general rule. In the case of New Madrid area earthquakes, the record of seismicity is very well documented and the physical characteristics in the area have been extensively studied. Thus, physical characteristics played a larger role in my decision for maximum magnitude in this area than they did in other parts of the EUS.

QUESTION 9 **Outline, briefly, the sources of information which formed the basis for your predictions of the largest magnitude.**

As in the case of other parameters, the observed record of seismic activity was the most important source of information that I used in estimating maximum magnitudes. Generally, once I defined a source zone, the most significant factor in choosing maximum magnitude was the largest earthquake in the historical and instrumental record of that zone. Another significant factor was the number of smaller earthquakes that occurred in that zone. This factor was considered because an exceptionally large number of smaller earthquakes in a given area may be indicative of the possibility of larger earthquakes.

QUESTION 10 **Did you follow a consistent procedure for predicting M_U? If so, briefly outline the procedure. Were you influenced by any constraints, e.g., limits of measurements scale, when considering your estimate?**

Yes, I followed a consistent procedure for predicting M_U. I began by defining the following categories of zones:

(1) A zone that is capable of generating a great intraplate earthquake (M_U=7.3).

(2) A zone that is capable of generating a large intraplate earthquake (M_U=6.8).

(3) A zone that is capable of generating a moderate-to-large intraplate earthquake (M_U=6.5).

(4) All other zones (M_U=6.0). This "background M_U" was chosen because I didn't feel comfortable assuming that there is any place in the EUS where a magnitude 6.0 earthquake could not possibly occur.

Once these categories were defined, I evaluated each zone to decide which category it belonged to.

My definition of a great intraplate earthquake was limited by the size of the 1811-1812 New Madrid, MO earthquakes and the fact that I am not aware of any intraplate earthquakes that are larger than the New Madrid events.

QUESTION 11 **What are the primary sources of uncertainty that you were trying to describe in determining the upper and lower limits for M_U?**

The primary sources of uncertainty that I considered in determining M_{UU} and M_{UL} were:

(1) I considered the magnitudes of the largest intraplate earthquakes of which I am aware.

(2) I didn't feel comfortable with allowing maximum magnitude estimates to get too low anywhere. Thus, my choice of lower limits for maximum magnitude are probably "on the high side".

(3) In my choice of upper limits for the more active zones, I considered the possibility that the interior of the North American plate could actually generate an earthquake larger than the New Madrid events.

QUESTION 12 Discuss, briefly, the various issues, e.g., clusters, catalog incompleteness, related to using recorded earthquake data as a basis for estimating the seismicity parameters (a,b).

Adjusting for aftershocks, clusters and dependent events seemed like too complex an issue for me to tackle given the amount of time that I had to respond to the questionnaires. So, initially (as best as I can remember) I didn't give much thought to the question of dependent events in the catalogue. Later, after being given the opportunity of using the EPRI catalogue, I decided to trust the identification of main events and dependent events made by EPRI.

Incompleteness of catalogues is such an obvious problem that it was clear from the start that I couldn't ignore it. In the first phase of this project (responses to Q2), I dealt with incompleteness by developing a qualitative method for correcting the activity rate in each zone for incompleteness.

For the most recent phase of this project (responses to Q9), I used the LLNL uniform approach to estimating (a,b) as an initial estimate, and then I intuitively decided whether or not to believe these results or somehow readjust them.

QUESTION 13 Outline, and rank, the principal sources, e.g., analysis based on your chosen catalog, the results of the LLNL "uniform approach", you used to develop your estimates of (a,b).

(1) An analysis based on my chosen catalogue and the results of the LLNL uniform approach were the most important sources that I used to develop my estimates of (a,b). These two sources were given approximately equal weight.

(2) Another important factor was a sense that b-values of approximately 1.0 were reasonable.

(3) In some cases I concluded (qualitatively) that the data and/or the LLNL uniform approach results just didn't "look right" to me, and so, I adjusted the values of (a,b). This aspect of my procedure for estimating (a,b) is very difficult to quantify, but it was used in a number of cases.

QUESTION 14 If you used a catalog recorded events as a basis for estimating (a,b), to what extent did you use analytical procedures to adjust for the aftershocks, etc and for incompleteness? Give a brief description of these procedures.

Adjusting for aftershocks, clusters and dependent events seemed like too complex an issue for me to tackle given the amount of time that I had to respond to the questionnaires. So, initially (as best as I can remember) I didn't pay too much attention to this issue. Later, after being given the option of using the EPRI catalogue, I decided to trust the identification of main events and dependent events made by EPRI.

In the first phase of this project (responses to Q2), I dealt with incompleteness by developing a method for estimating (qualitatively) an "equivalent period of time for completeness", T, for each zone. Then I assumed that the catalogue was approximately complete for the past T years. T was estimated "visually" from the lists of earthquakes in each of my source zones provided by LLNL. I also "visually" fit a line through the data in the plots (provided by LLNL) of the cumulative number of earthquakes in different magnitude ranges for each of my source zones. The "equivalent period of time for completeness" was used to convert my a-value estimates into units of number of events per year.

For the most recent phase of this project (responses to Q9), I used the LLNL uniform approach to estimating (a,b) as an initial estimate, and then I intuitively decided whether or not to accept these results as they were or to somehow readjust them. I suspect that in at least 50% of the source zones, my results were quite similar to the LLNL uniform approach results.

QUESTION 15 Identify and discuss, briefly, some of the significant issues impacting characterization of the seismicity of the EUS.

I think that the most significant issue impacting characterization of the seismicity of the EUS is that for most (if not all) of this region, the cause of the earthquakes is unknown. The historical and instrumental records of seismicity are the only truly viable sources of information that we have. Yet, I find it hard to accept that this record is anything more than just a snapshot in time. It seems to me that when using the LLNL methodology, we are to some extent assuming that the process that generates EUS earthquakes is stationary. That is, a source zone is either active or not active; if it is active, then it has a particular set of seismicity parameters. It is possible, however, that the pattern of seismic activity in the EUS changes with time. That would imply that an area of the EUS that has been very active for the past several hundred years could cease to be active and a previously inactive area could become active. I tried to address that possibility by choosing the large mega-zone as an alternative map. That map represents the hypothesis that "anything can happen" in the EUS, and the seismicity parameters for the large mega-zone are intended to characterize the general nature of seismic activity in the interior of the North American plate.

QUESTION 16 What do you consider to be the major sources of uncertainty in predicting the seismicity parameters (a,b)?

(1) Do we have a good enough data base from which to estimate (a,b)? Is the time period of this data base long enough? Is the catalogue completely and accurately recorded?

(2) Is the process that generates earthquakes in the EUS stationary?

QUESTION 17 Were the alternates presented in the seismicity questionnaires for modeling potential correlation between (a,b) adequate for you to express your views about your joint uncertainty about the seismicity parameters? Discuss your views on correlation between a and b.

I realized, after the first feedback meeting, that this was a difficult issue to deal with. It seemed to me that unless I was very careful in estimating the bounds on (a,b) for each case, there was a good chance that some of the implications of my inputs would yield a much wider range of possible recurrence relationships than I had intended. The alternatives presented for modeling correlation between (a,b) helped me to understand the implications of the uncertainty bounds that I chose for (a,b). In the most recent phase of this project (Q9), I chose fully correlated because I thought that option made it easier for me to keep track of the range of possibilities that I intended.

SEISMICITY INPUT DOCUMENTATION FOR EXPERT 7
QUESTIONNAIRE Q8

QUESTION 1 **Discuss briefly the adequacy of the principal sources of information, including physical characteristics and observational data, as a basis for identifying source zones.**

In most parts of the Eastern U.S. neither the seismicity nor the understanding of the geologic and tectonic features are adequate to outline well-defined source zones.

QUESTION 2 **Outline your principal bases for identifying zones? To what extend did you rely on tectonic and geophysical features as a source of zonation? What, if any, historical seismicity and other observational data did you consider in your development of seismic source zones?**

a. Seismicity (historic and instrumental) is the single most important data set to identify a region as a source zone.

b. Geologic and geophysical data are used in addition to seismicity to define the shape and boundaries of a source zone.

c. Only in one case Meers Fault (Oklahoma) that the zone could be defined on the basis of geology.

QUESTION 3 **Identify some of the factors, such as scaling, lower bound magnitude, which influenced your development of the EUS zonation maps. Rank the relative importance of each of these factors, and, if possible, explain how these factors influenced your choice.**

The scale of the seismic zones is chosen for a regional hazard assessment. The zones are too broad to be used for site-specific hazard calculation. This latter effort requires micro-zonation. The lower bound magnitude made some difference by broadening specific zones and reducing the areas of "background". Had M_{LB} been 5.0, background would have been larger in area.

QUESTION 4 **Describe, briefly, the influence of, and your use of, these features in the development of your zonation maps.**

Background helped account for diffused seismicity where $M_b \leq 5$ in general. This took place of many poorly defined seismic zones. I used three scales.

a. A well defined relatively small source zone to define regions such as New Madrid, La Moodis, etc. of known significant earthquakes and for seismogenic features. These zones may be enclosed in zones described in (b).

b. Larger zones which are characterized by diffused but distinctive seismicity and tectonics. Many zones fall into this category. Some of these zones are quite large.

c. Background- all regions not included in (a) or (b). Three areas have varying degrees of seismicity and could have significant potential. Yet I cannot distinguish these as distinct on geological geophysical data.

QUESTION 5 **Did you feel that these two ways of describing uncertainty provided you with adequate means of expressing your state of knowledge regarding zonation of the EUS? Discuss the types of uncertainties you had identified and attempted to model by specifying a probability of "existence" of a zone and/or alternative zone boundaries.**

I assumed that each zone exits with equal likelihood. There is some probability incorporated in an implicit way by the procedure outlined in 4. Examples are the "well defined" zones such as New Madrid that are shown as a specific zone within a larger zone. The "alternate zone" idea sounded great at first when it was introduced in the EPRI study. However, this is practical only for regional or site-specific studies. For the general eastern U.S. study there is no practical way of doing this unless the level of effort is raised by order(s) of magnitude.

QUESTION 6 Discuss briefly what type of uncertainties you considered when specifying the bounds for seismicity parameters.

None other than described under questions 4 and 5.

QUESTION 7 what does the terminology "95 percent confidence or uncertainty bounds" mean to you? How did you interpret it?

95 confidence bounds: Probability is 0.95 that the "true value" is within the bounds of the parameter estimate (bounds).

QUESTION 8 Discuss, briefly, the significant issues related to predicting the largest magnitude earthquake that can be expected to occur in a source zone.

Most physical parameters (such as the lengths of fault or fault segments, fault width, stress drop, in-situ stress, strain accumulation rate, etc.) are difficult to estimate for the Eastern U.S.

QUESTION 9 Outline, briefly, the sources of information which formed the basis for your predictions of the largest magnitude.

I relied primarily on two observed parameters:

a. Largest magnitude event in a given source zone.

b. Magnitudes of intraplate earthquakes over the globe, and I believe there is a characteristic maximum earthquake for each zone.

QUESTION 10 **Did you follow a consistent procedure for predicting M_U? If so, briefly outline the procedure. Were you influenced by any constraints, e.g., limits of measurements scale, when considering your estimate?**

For estimating upper bound magnitude (M_{UB}) I followed the following procedure:

If the largest earthquake that occurred in a source zone is $(M_b)^*$, then for

$(M_b)^* < 5.0$	$M_{UB} = (M_b)^*$ plus 1
$5.0 \leq (M_b)^* < 6.0$	$M_{UB} = (M_b)^* + 0.75$
$6.0 \leq (M_b)^*$	$M_{UB} = (M_b) + 0.5$

The following are considered in the above formulation

a. Uncertainty of $(M_b)^*$, for small $(M_b),^*$ is large i.e., when $(M_b{}^* \leq 5/0)$.

b. Probability of missing an event of $(M_b)^* < 5.0)$ is significant.

c. The compression of m_b scale as we go to large magnitudes.

Had we used an M_s or M_w (moment-magnitude), the added increments would have been different.

QUESTION 11 **What are the primary sources of uncertainty that you were trying to describe in determining the upper and lower limits for M_U?**

The uncertainty listed in 10 plus the uncertainty of defining M_U in terms of the maximum magnitude observed event, given that the time period over which data are available is limited.

QUESTION 12 Discuss, briefly, the various issues, e.g., clusters, catalog incompleteness, related to using recorded earthquake data as a basis for estimating the seismicity parameters (a,b).

We need to calculate earthquake hazard due to all events rather than for those that obey the exponential Poisson distribution. Thus we should remove as few events as possible from the catalog.

There are several approaches:

a. Take out as few events as possible to reduce severe effects of clustering and still use the exponential-Poisson model.
b. Eliminate clustering, use exponential-Poisson model and then calculate hazard independently for those events removed.
c. Use a model other than Poisson.

I find approach "a" is most practical if applied the following way: (1) Ignore the foreshocks. They are too few. (2) Remove "aftershocks". Define aftershocks as "events clustered" in time and space and with magnitudes at least one magnitude less than the main shock. (3) After removing aftershocks, add the normal "background" seismicity for that zone.

There are good examples of events migrating along a "fault zone" over several months or years (e.g., New Madrid, Gaza-USSR, Song Pan - China). A typical de-clustering routine will take out such independent events.

QUESTION 13 Outline, and rank, the principal sources, e.g., analysis based on your chosen catalog, the results of the LLNL "uniform approach", you used to develop your estimates of (a,b).

I used LLNL values except where LLNL fits to seismicity data appeared to be poor (where data are few). In such cases I fitted the data generally with a "bias" that b = 1.0.

QUESTION 14 **If you used a catalog recorded events as a basis for estimating (a,b), to what extent did you use analytical procedures to adjust for the aftershocks, etc and for incompleteness? Give a brief description of these procedures.**

Used LLNL catalog.

QUESTION 15 **Identify and discuss, briefly, some of the significant issues impacting characterization of the seismcity of the EUS.**

No information was given on this question.

QUESTION 16 **What do you consider to be the major sources of uncertainty in predicting (a,b)?**

No information was given on this question.

QUESTION 17 **Were the alternates presented in the seismicity questionnaires for modeling potential correlation between (a,b) adequate for you to express your views about your joint uncertainty about the seismicity parameters? Discuss your views on correlation between and and b.**

No information was given on this question.

SEISMICITY INPUT DOCUMENTATION FOR EXPERT 10
QUESTIONNAIRE Q8

QUESTION 1 **Discuss briefly the adequacy of the principal sources of information, including physical characteristics and observational data, as a basis for identifying source zones.**

The principal elements for identification of source zones consists of seismicity and geological/geophysical data. The geological data at earthquake depths has to be inferred from geophysical data or extrapolated regional geological data.

The seismicity data base has been substantially improved in the last several years and for purposes of selecting source zones, is adequate. With a few exceptions, the geophysical data base is spotty on a regional basis and even more so on a local basis for use in correlation to epicentral locations.

While many seismologists are willing to use the seismicity data base exclusively since earthquakes are the best manifestation of a source zone, the observational time period for earthquakes is very short and extrapolation to longer time must be done on a geological basis.

Identifiable tectonic structures associated with earthquakes are the best criteria for identifying source zones, unfortunately, the data base [geophysical] for doing this is variable.

Consequently, experts either ignore it because of its limitations or use it; but without accounting for its variations. Areas where data are absent often are those assigned a low probability of occurrence, out of ignorance rather than knowledge.

QUESTION 2 **Outline your principal bases for identifying zones? To what extend did you rely on tectonic and geophysical features as a source of zonation? What, if any, historical seismicity and other observational data did you consider in your development of seismic source zones?**

Identified zones were selected on the basis of seismic, geological, and geophysical characteristics. Geophysical data and known tectonics, where available in sufficient detail, were heavily relied on. Historical seismicity was also heavily relied on. Of particular interest are those earthquake epicentral areas which have comparative geological/geophysical features.

QUESTION 3 **Identify some of the factors, such as scaling, lower bound magnitude, which influenced your development of the EUS zonation maps. Rank the relative importance of each of these factors, and, if possible, explain how these factors influenced your choice.**

Geophysical maps in the eastern United States [EUS] exist at scales ranging from 1:5,000 to 1:1,000,000 and the resolution is dependent on these scales.

Earthquake magnitudes below 3.5 were not considered unless the earthquakes had a definable pattern and/or correlated with identifiable tectonic features.

The factors considered were: 1] the presence of earthquakes and the correlation of tectonic features to the larger earthquakes [$\geq$ 4.5]; 2] the presence or absence of geological/geophysical data to identify tectonic features at an appropriate scale, i.e.

identification of tectonic features at 5-10 mile lengths or greater; 3] orientations and history of the tectonic feature[s], if known; 4] physical characteristics of the feature versus the surrounding rock, for example, rigid versus non-rigid crustal blocks. A numerical rank was not assigned to these.

QUESTION 4 **Describe, briefly, the influence of, and your use of, these features in the development of your zonation maps.**

The background or complimentary zones are generally a manifestation of ignorance of "correlatable" tectonics and seismicity. This was and is many times due to an inadequate geological/geophysical data base. At the required scale, it appears that similar tectonic features exist where earthquakes have occurred and where they have not. This could be due to an insufficient observational time for earthquakes or lack of necessary detail on the tectonic features or both. The use of background zones, while an attempt to express uncertainty, tends to homogenize the risk of assigning an even distribution of earthquake over a larger area than the individual structures which causes them.

This either unduly penalizes a site which is not near or on an earthquake structure, or optimistically considers the threat as having a much lower probability than is real if it is on or near an earthquake producing structure. Depending on the size of the area chosen as compared to the "real" size of a causative structure, the error in probability could be substantial.

QUESTION 5 **Did you feel that these two ways of describing uncertainty provided you with adequate means of expressing your state of knowledge regarding zonation of the EUS? Discuss the types of**

uncertainties you had identified and attempted to model by specifying a probability of "existence" of a zone and/or alternative zone boundaries.

The seismicity parameters depend on the stress field, the size of the structure, and the maximum dimensions of structure involved in one event. Clearly, there is uncertainty with respect to all of these elements. An estimate of an upper bound earthquake is gleaned from the past seismic history and in particular, the nature of the tectonic structures associated with past earthquakes.

The uncertainties include: the length of the seismic history compared to the length of extrapolation; the consistency of the occurrence of given magnitudes in a region or on a structure; the degree of correlation between the earthquakes and the geological structures; the expected dimensions of fault failure based on the estimated stress field amplitude, and the orientation, nature, and rheology of suspect of identified faults.

I do not believe that the uncertainty, particularly with respect to an individual site, is adequately expressed by either alternate zones, their existence, or change in boundaries.

QUESTION 6 **Discuss briefly what type of uncertainties you considered when specifying the bounds for the seismicity parameters.**

QUESTION 7 **What does the terminology "95 percent confidence or uncertainty bounds" mean to you? How did you interpret it?**

The 95 percent confidence bound meant little or nothing since the uncertainties are so great. It was interpreted in terms of a value which required a high degree of conservatism [not to exceed numbers] in the estimated time for which they were intended to apply, 50 years or thereabouts.

QUESTION 8 **Discuss, briefly, the significant issues related to predicting the largest magnitude earthquake that can be expected to occur in a source zone.**

The largest earthquake prediction depends on the size of the structure, the distribution of stress [whether localized on a few or over many structures] and the brittleness of the structure [rheology] whether it would creep or break. Critical to the upper magnitude is the time involved in stress built up and dissipation time. If all dissipation occurs in say a few hundred years, through minor events and creep, the maximum earthquake would be small as compared to areas where there is little dissipation and stress can accumulate for several hundred years and result in rigid deformation.

QUESTION 9 **Outline, briefly, the sources of information which formed the basis for your predictions of the largest magnitude.**

See answer to questions 3 and 5.

QUESTION 10 **Did you follow a consistent procedure for predicting M_U? If so, briefly outline the procedure. Were you influenced by any constraints, e.g., limits of measurements scale, when considering your estimate?**

The only way a consistent procedure could be established for M_U would be to have consistent input data as given in 3, 5, and 8 above. Since these data are inconsistent, any procedure for selecting M_u must be deficient in certain input elements and therefore, the results would be inconsistent.

QUESTION 11 **What are the primary sources of uncertainty that you were trying to describe in determining the upper and lower limits for M_U?**

The degree of knowledge [or ignorance] relative to the elements given in 3, 5, and 8.

QUESTION 12 **Discuss, briefly, the various issues, e.g., clusters, catalog incompleteness, related to using recorded earthquake data as a basis for estimating the seismicity parameters (a,b).**

The traditional approach for estimation of seismicity parameters is to deal with main shock events and with completely reported segments of the earthquake catalog. We have attempted to accomplish this by eliminating all obvious foreshocks/aftershocks from our catalog. In addition, as a result of much prior work, we have identified with a reasonable degree of confidence the completely reported time intervals for various magnitude events listed in the catalog.

QUESTION 13 **Outline, and rank, the principal sources, e.g., analysis based on your chosen catalog, the results of the LLNL "uniform approach", you used to develop your estimates of (a,b).**

Seismicity parameters were derived based on analyses of the earthquake catalog maintained by Weston Geophysical Corporation. This earthquake catalog is the result of more than two decades of research on the more important seismic events and a complete review and integration of other existing catalogs. Entries in the other major catalogs, such as the LLNL and EPRI catalogs, were routinely compared to the data base we maintain to identify any major discrepancies. Major discrepancies were handled by reverting back to the original accounts or sources for the events in question and using this information to determine the best set of earthquake parameters.

QUESTION 14 **If you used a catalog recorded events as a basis for estimating (a,b), to what extent did you use analytical procedures to adjust for the aftershocks, etc and for incompleteness? Give a brief description of these procedures.**

Seismicity parameters were determined using a catalog wherein obvious foreshock and aftershock sequences were flagged and later removed during statistical analyses. Obvious fore- or aftershocks included only those that were closely, spatially, and temporarily linked to a main shock. Formal analytical cluster-analyses were not employed. Completeness intervals for magnitude groups were determined for various sub-regions. These completeness intervals were derived given our understanding of seismograph network deployments and population expansions. For example, in the NEUS, significant advances in seismographic instrumentation occurred in the mid- to late 1970's. Characteristics of the expanded networks suggest to us that all magnitude 3 and larger events have been reported during this time. Further, due to the distribution of early population centers in the NEUS, it is concluded that major events 6 have been completely reported for 250 to 300 years. Variations in seismographic instrumentation and population expansions in other regions of the EUS were considered in estimation of completeness intervals.

QUESTION 15 **Identify and discuss, briefly, some of the significant issues impacting characterization of the seismicity of the EUS.**

See answers to questions 3, 5, and 8.

QUESTION 16 What do you consider to be the major sources of uncertainty in predicting the seismicity parameters (a,b)?

There are several principal sources of uncertainty in predicting seismicity parameters. These are summarized below in perceived order of importance. The most important are listed first.

a. Completeness interval for various magnitudes - The completeness interval assumed for the purpose of estimating earthquake frequencies can significantly affect estimates of a- and b-values. Completeness intervals should therefore be carefully examined in the context of timing of seismograph deployments and population expansions.

b. Magnitude calculations or estimates - Because the earthquake catalog for the EUS contains a mix of historical and instrumental events, it is important to convert all events to a uniform magnitude scale, such as mb. Empirical relationships among the parameters mb vs. I0, mb vs. ML, mb vs. mbLg, etc., can have an important effect on seismicity parameter results; these relations should therefore be verified for usage on a regional or local basis.

c. Magnitude grouping - The methodology used to group earthquake magnitudes and the magnitude chosen to characterize a particular group of magnitude, e.g. low magnitude of cell vs. center magnitude or average magnitude, can affect seismicity parameter estimates.

QUESTION 17 Were the alternates presented in the seismicity questionnaires

for modeling potential correlation between (a,b) adequate for you to express your views about your joint uncertainty about the seismicity parameters? Discuss your views on correlation between a and b.

The largest concern that I have with the developed relationship is that there is an implied functional relationship between the earthquakes magnitudes. If one were dealing with a single earthquake producing fault or fault systems then the relationship between smaller earthquakes and larger earthquakes may be controlled by the stress field and the rheologies, asperities, etc. of the fault lithologies and a functional relationship of small to large magnitudes would serve as a predictor. However, in a region the smaller earthquakes may be the result of smaller fault movement and the larger ones due to larger faults independent of the smaller faults. Therefore, if the curve is to be used in a regional sense, as applied to a site, one should know whether or not the site is near a large fault or smaller fault. The use of a regional functional relationship to a larger active fault would badly underestimate to probability of maximum earthquake occurrence.

The controlling factor in the establishment of the curve is the size of area chosen; other elements, errors, incompleteness, etc., are not significant contributors if a well documented earthquake such as that produced by EPRI is used.

Also see answers to questions 3, 5, 8, 12, and 13.

SEISMICITY INPUT DOCUMENTATION FOR EXPERT 11
QUESTIONNAIRE Q8

QUESTION 1 **Discuss briefly the adequacy of the principal sources of information, including physical characteristics and observational data, as a basis for identifying source zones.**

The available seismicity catalogs are sufficient to present the historical seismicity. The major question in the data is whether sufficient recording time has been available to provide a complete statistical distribution of historical seismicity. Other data (potential and seismic velocity) are sufficient, but with considerable more seismic data, significant improvements could be incorporated in the determination of zones. Potential data were used extensively and no significant improvement in this data should be expected.

QUESTION 2 **Outline your principal bases for identifying zones? To what extend did you rely on tectonic and geophysical features as a source of zonation? What, if any, historical seismicity and other observational data did you consider in your development of seismic source zones?**

Seismic zones were defined on the basis of near-surface geology, crustal composition, crustal thickness, and seismicity, Tectonic and Geophysical features account for about 70 percent of the definition and seismicity the remaining 30 percent. The contribution of a particular tectonic or geophysical feature to the definition of individual zones was dependent on the character of the seismicity. For example, in the Piedmont the earthquakes occur only as shallow events with mechanisms similar to that of reservoir induced events.

The general pattern of seismicity, available from most earthquake catalogs, was used to suggest active zones. However, detailed aftershock and seismic net studies were given considerable weight in determining the style of the earthquakes occurrence. The style was then used to choose appropriate tectonic and geophysical features to help define the border of the seismic zones.

QUESTION 3 Identify some of the factors, such as scaling, lower bound magnitude, which influenced your development of the EUS zonation maps. Rank the relative importance of each of these factors, and, if possible, explain how these factors influenced your choice.

The scale of resolution was more than sufficient. A zone boundary is diffuse, not narrow, since stress fields in the crust require more than 100 km decay to the level of local components of the stress field. However, most seismic zones are at least 100 km wide except where an axis of a relic rift was identified. Seismicity was used primarily to decide if a zone was active, and hence, the lower bound magnitude was not a significant factor.

For a specific site the microzonation would be strongly dependent on the tectonic setting of the seismicity. In the Piedmont, a specific site analysis would require an analysis of geologic parameters of near surface rocks as well as seismic history. In contrast, in the southeastern Tennessee areas, an analysis based on non-surface (5 to 20 km deep) crustal properties would be integrated into the analysis.

The estimate of a and b values should include all available seismicity. Elimination of less than m=5 events would probably bias (because of difficulty in calculating estimates) the estimates in areas of sparse seismicity, but I would not expect them to change.

QUESTION 4 **Describe, briefly, the influence of, and your use of, these features in the development of your zonation maps.**

I avoided the background and complementary zones as much as possible. Instead, I tried to relate the significant seismicity of a zone to a characteristic dominant mechanism and use that as the basis for a zone.

QUESTION 5 **Did you feel that these two ways of describing uncertainty provided you with adequate means of expressing your state of knowledge regarding zonation of the EUS? Discuss the types of uncertainties you had identified and attempted to model by specifying a probability of "existence" of a zone and/or alternative zone boundaries.**

Yes, the methods were sufficient. The probability of existence was largely determined by my direct knowledge of the seismicity in each zone and the number of events in catalog.

QUESTION 6 **Discuss briefly what type of uncertainties you considered when specifying the bounds for seismicity parameters.**

The upper bound magnitude was determined by the tectonic setting of the events and its uncertainty by the strength of the interpretation of the tectonic setting.

QUESTION 7 **What does the terminology "95 percent confidence or uncertainty bounds" mean to you? How did you interpret it?**

Estimate the standard deviation based on distribution of the central 60 percent of the data, and double it. Modify slightly depending on whether I believe the data were normally distributed according to the amplitude or Log (amplitude).

QUESTION 8 **Discuss, briefly, the significant issues related to predicting the largest magnitude earthquake that can be expected to occur in a source zone.**

The maximum magnitude was:
5.75 for Piedmont type, shallow (type event is New Brunswick)
6.5 for closed rift-like continental structures that are open to oceanic or extensional crust or show significant seismic activity.

QUESTION 9 **Outline, briefly, the sources of information which formed the basis for your predictions of the largest magnitude.**

The largest observed earthquakes in their respective tectonic setting (see Question 8).

QUESTION 10 **Did you follow a consistent procedure for predicting M_U? If so, briefly outline the procedure. Were you influenced by any constraints, e.g., limits of measurements scale, when considering your estimate?**

(see Question 8-9)

QUESTION 11 **What are the primary sources of uncertainty that you were trying to describe in determining the upper and lower limits for M_U?**

Tectonic and magnitude determination.

QUESTION 12 **Discuss, briefly, the various issues, e.g., clusters, catalog incompleteness, related to using recorded earthquake data as a basis for estimating the seismicity parameters (a,b).**

The greatest uncertainty comes not from the recorded data (which can generally be corrected for incompleteness) but from non-stationarity in the seismicity (for example, Charleston before and after 18876). I think the strong removal of aftershocks could remove some of this uncertainty.

QUESTION 13 **Outline, and rank, the principal sources, e.g., analysis based on your chosen catalog, the results of the LLNL "uniform approach", you used to develop your estimates of (a,b).**

Plots of numbers on events versus magnitude (provided) tempered by an analysis of completeness and contamination by aftershocks.

QUESTION 14 **If you used a catalog recorded events as a basis for estimating (a,b), to what extent did you use analytical procedures to adjust for the aftershocks, etc and for incompleteness? Give a brief description of these procedures.**

see Question 13.

QUESTION 15 **Identify and discuss, briefly, some of the significant issues impacting characterization of the seismicity of the EUS.**

The most significant issues impacting characterization of eastern United States Seismicity are the unanticipated events (surprises), lack of understanding of aftershock processes, and a means of direct detection of potentially active tectonic zones.

QUESTION 16 **What do you consider to be the major sources of uncertainty in predicting (a,b)?**

Sparse data (less than 25 events) and non-stationarity of the tectonic process.

QUESTION 17 Were the alternates presented in the seismicity questionnaires for modeling potential correlation between (a,b) adequate for you to express your views about your joint uncertainty about the seismicity parameters? Discuss your views on correlation between a and b.

Yes Discussed previously. a and b are correlated, but the effect of this can be minimized if constrain values to a mid-point in the data.

SEISMICITY INPUT DOCUMENTATION FOR EXPERT 12
QUESTIONNAIRE Q8

QUESTION 1 **Discuss briefly the adequacy of the principal sources of information, including physical characteristics and observational data, as a basis for identifying source zones.**

The sources of information that I used to make the seismic source zone interpretations are shown in Figs. 2 and 3 attached. The adequacy of these data has to be evaluated in terms of their usefulness for defining sources and in terms of their quality.

I will start with the stress data. I felt the stress data were useful and adequate to make the limited determination that there are no unusual, anomalous sources of lithospheric stress in the central and eastern parts of the United States, and that overall the stress field is somewhat uniform. The stress field beyond that is not very useful for making specific interpretations, since it is not possible to resolve the three-dimensional aspect of the stress at any specific location; the data samples are too sparce and local contributions, stress amplification and other possible influences could not be resolved.

With regard to the Bouguer gravity anomaly data, I made most use of these, since I felt the principal basis for localizing stress would be discontinuities reflected as lateral changes in density in the upper part of the Earth's crust. In addition, these data in combination with the magnetic anomaly data are very useful for defining broad geographic areas of contrasting crustal rocks that could define areas having different geomechanical responses to imposed stresses. I used the unfiltered gravity data and the 125 and 250 high pass filter gravity data for my primary interpretations.

With respect to the magnetic anomaly data, these were used to supplement the gravity data for defining the boundaries of sources in certain areas. Generally, I did not specifically use the magnetic data to identify boundaries, but only to supplement the gravity data. One additional use of the magnetic data was to define general areas of the upper part of the crust that have contrasting rock material properties, that is, granitic rocks vs. basic rocks. The magnetic data are particularly useful to define lateral density discontinuities.

The next set of data I used was cumulative seismic moment. The seismic moment data were used in rather limited cases to help define boundaries of sources where other data were not adequately definitive. The seismic moment data was also used in the upper Mississippi embayment to differentiate between source boundaries in detail. In some situations, I used historic seismicity plots to help position source boundaries in areas where there was not definitive information in the geophysical data.

The tectonic map of the United States was used to refine source boundaries and to delineate tectonic structure specific sources.

QUESTION 2 **Outline your principal bases for identifying zones. To what extend did you rely on tectonic and geophysical features as a source of zonation? What, if any, historical seismicity and other observational data did you consider in your development of seismic source zones?**

The principal basis for defining sources was the combination of Bouguer gravity anomalies and magnetic anomalies. These data were supplemented by the seismicity data and by geologic data in some situations where I felt those two sets of data added to the source definition. I relied heavily on the assumption that earthquake sources are associated with definable tectonic features of the Earth's crust, and that these features would be identifiable either in the tectonic map of the United States or by geophysical anomalies.

I considered historical seismicity only to the extent that it supplemented definition of boundaries in some areas where the geophysical and tectonic data were not definitive.

QUESTION 3 **Identify some of the factors, such as scaling, lower bound magnitude, which influenced your development of the EUS zonation maps. Rank the relative importance of each of these factors, and, if possible, explain how these factors influenced your choice.**

With regard to scale of resolution of the zonation maps, I was somewhat influenced by my view that at the scale of approximately 1:5 million, with which I was working, I did not need to look in detail at specific geological features to determine the zonation boundaries. In other words, I think that given a much larger scale map, say 1 to a million to work from, the zonation boundaries would have required a more detailed look at local geology than I felt was necessary for this small scale. So, I would think that the zonation boundaries are relatively less precisely located at this scale than they would be at a larger scale. But, it is not clear to me that this contributes to the uncertainty in the hazard computation using maps of this scale.

The lower bound magnitude did not influence my zonation in any way. I attempted, first of all, to define seismic zones on the basis of geophysical and geological data without consideration of the maximum or lower bound magnitude that these zones might be able to generate. With regard to the lower bound magnitude, however, I did make the assumption that the defined seismic zones would not define all of the seismicity; the background and complementary sources in my interpretation are meant to pick up the level of seismicity that would not be included in individual source interpretations.

QUESTION 4 Describe, briefly, the influence of, and your use of, these features in the development of your zonation maps.

For development of the zonation map, the background and complementary sources were used to identify areas of seismicity that I could not associate with identifiable tectonic features at the scale with which I was working. I made the assumption that identifiable tectonic features would have some potential of being distinct seismic sources. This assumption was made independently of whether the rates of activity in those sources or the maximum or minimum magnitudes in them differed from adjoining sources. So, in my interpretation, many of the sources will have similar rates of activity, similar maximum magnitudes and so on. I simply meant to distinguish them as being identifiable features in the Earth's crust that could localize earthquakes. The background and complementary sources simply represent activity in those areas where I could not identify specific tectonic features.

QUESTION 5 Did you feel that these two ways of describing uncertainty provided you with adequate means of expressing your state of knowledge regarding zonation of the EUS? Discuss the types of uncertainties you had identified and attempted to model by specifying a probability of "existence" of a zone and/or alternative zone boundaries.

The structure of the interpretation approach is amenable to expressing alternative interpretations. The background and complementary zones are adequate in my judgement to permit expression of the alternative interpretations that one could wish to propose. This, of course, may require developing multiple maps.

The types of uncertainties that I attempted to express in modeling the probability of existence of the sources were simply my judgements of the likelihood that the source was, in fact, active in the contemporary stress regime. The alternative, in my interpretation, is express as the background or complementary zone.

QUESTION 6 **Discuss briefly what type of uncertainties you considered when specifying the bounds for seismicity parameters.**

My response here considers the parameters a and b of the frequency-magnitude equation, and the upper bound magnitude.

First of all, I have assumed that the basic properties of an earthquake source are:

1. seismicity parameters are constant throughout the source; and

2. the upper bound magnitude applies to the entire source.

With respect to the parameters a and b, I have made two governing assumptions:

First, with respect to the seismicity parameter b, I have assumed this parameter to be stable over large tectonic regions. I would permit, for example, differences in this parameter between a stable continental interior, a Paleozoic orogenic system such as the Wichita or the Appalachian systems, and continental boundary sources. The data are adequate to make some minor distinctions of the parameter among these regions, and I used these distinctions to make subjective interpretations of what the value of the parameter should be for seismic sources within those general tectonic environments. With respect to the uncertainty on the parameter b, I have assumed that the parameter is determined with reasonable certainty. I have allowed an uncertainty of $\pm$ .15 depending on my confidence in the value within the general crustal environment of the seismic source.

Second, with respect to the parameter a, I have assumed that this value can be determined from the historic seismicity sample for each source, and

I have allowed it to vary from source to source depending on the historic rate of occurrence of earthquake activity within that source. The value is determined by anchoring the frequency magnitude curve to the lowest magnitude level for which I considered the reporting to be complete, and then the rate of activity is computed from the frequency magnitude formula. I have assumed an uncertainty of ±1/2 magnitude in my assessment of the magnitude for which the reporting is complete and have taken the resulting range in a to be the uncertainty.

With respect to maximum magnitude, I have made strong use of the historic seismicity data for each source of analogies with worldwide data for similar tectonic environments. My principal governing data are tectonic similarities with other regions and the size of tectonic features within the source. For example, the uncertainty in the maximum magnitude estimate for the New Madrid seismic source is relatively low, based on a world wide observation that earthquakes of this size simply are exceedingly rare in intraplate regions. Based on this observation, I assume that this is a maximum event for this seismic source with little uncertainty. For other areas, for example, sources within the stable platform tectonic environment are given higher levels of uncertainty. The higher level of uncertainty generally is related to my assessment of the order of importance of the tectonic feature with which the source is associated.

QUESTION 7 What does the terminology "95 percent confidence or uncertainty bounds" mean to you? How did you interpret it?

I interpret the terminology to mean a very high degree of confidence that the actual value given for the parameter in general, falls within the range of the upper and lower bound stated.

QUESTION 8 **Discuss, briefly, the significant issues related to predicting the largest magnitude earthquake that can be expected to occur in a source zone.**

The principal issues related to the largest earthquake that might be expected within a source are the tectonic order and size of the tectonic features. I have assumed that large scale, first order tectonic features equate to larger maximum earthquakes in general. However, this is very much modulated by tectonic analogy with experience worldwide. I generally put higher degrees of uncertainty on my assessments of maximum magnitude where larger tectonic features existed and worldwide experience indicated that only moderate size earthquakes might be expected.

QUESTION 9 **Outline, briefly, the sources of information which formed the basis for your predictions of the largest magnitude.**

The sources of information are basically those that I used to define the seismic sources themselves, plus a compilation of worldwide earthquake activity associated with intraplate regions developed by EPRI under project 2556-12. This document, although in limited release, has been distributed to scientists working in this subject area.

QUESTION 10 **Did you follow a consistent procedure for predicting M_U? If so, briefly outline the procedure. Were you influenced by any constraints, e.g., limits of measurements scale, when considering your estimate?**

With respect to the first part of this question, I refer back to Question No. 8. I was not limited by the magnitude scale used. All of my estimates are made in terms of m_b, which I have assumed to saturate at about magnitude 7 to 7 1/2.

QUESTION 11 What are the primary sources of uncertainty that you were trying to describe in determining the upper and lower limits for M_U?

The uncertainty on M_u reflects my uncertainty on the processes of earthquake occurrences in intraplate tectonic regions, the uncertainty on the orientation of structures within a specific source, the relationship of the overall stress regime to earthquake occurrences within a source, and limitations of data from worldwide analogous regions.

QUESTION 12 Discuss, briefly, the various issues, e.g., clusters, catalog incompleteness, related to using recorded earthquake data as a basis for estimating the seismicity parameters (a,b).

I have assumed that clustering of activity results in some error to the rates of activity determined from the historic catalog, but this was not taken into specific account in my estimates of the a value. The incompleteness of the catalog is, of course, the most serious difficulty in determining a and b values from historic record. Second to this is the length of the data base itself. I have accepted that the incompleteness in the catalog has been properly accounted for by the Lawrence Livermore model. For most of the sources, I have made the assumption that the data sample is not adequate to determine, independently, the a and b values. For this reason, I have placed very strong priors on b, and have allowed a to be determined from the magnitude value above which the historic seismicity is assumed complete.

QUESTION 13 Outline, and rank, the principal sources, e.g., analysis based on your chosen catalog, the results of the LLNL "uniform approach", you used to develop your estimates of (a,b).

I referred to question 12 with this answer.

QUESTION 14 **If you used a catalog of recorded events as a basis for estimating (a,b), to what extent did you use analytical procedures to adjust for the aftershocks, etc and for incompleteness? Give a brief description of these procedures.**

I refer to my response to question 12.

QUESTION 15 **Identify and discuss, briefly, some of the significant issues impacting characterization of the seismcity of the EUS.**

Again, I refer my response to question 12. I believe that the most significant issue is the length of sample available to determine seismicity parameters within a restricted source for regions of such low seismicity rates such as the eastern North American Continent. The issue of whether b is essentially a constant value that approximately equals to 1 or whether it is a value that varies significantly from one source to another is of considerable importance. I have assumed with a high.degree of certainty, in my mind, that b is essentially a constant parameter, approximately equal to 1. The issue of variation of seismicity rates from one source to another is also of considerable importance. Typically, one would like to assume that seismicity rates are related to tectonic strain rates. Within a model of a flawed, rigid lithospheric plate driven by boundary forces, the validity of this assumption becomes less clear. That is, there is no indication in the available data that tectonic rates should vary from one location to another within the region. Notwithstanding, the uncertainties about variations in rates of activity in the intraplate region, I have made the assumption that the best available information to determine rates of earthquake activity for a source are the historic earthquakes. Where possible, the a value has been determined from the historic sample within a source. Where the sample was not adequate in my judgement for this purpose, I estimated rates from analogous sources.

QUESTION 16 What do you consider to be the major souces of uncertainty in predicting the seismicity parameters (a,b)?

The major source of uncertainty, in my mind, is the fundamental lack of knowledge about strain release mechanisms. Other important sources of uncertainty relate to the length of the data sample. If we had either a longer sample or a better understanding of the process, the uncertainty could be reduced.

QUESTION 17 Were the alternates presented in the seismicity questionnaires for modeling potential correlation between (a,b) adequate for you to express your views about your joint uncertainty about the seismicity parameters? Discuss your views on correlation between and and b.

The answer to the first part of this question is yes. I had no difficulty expressing my views about the uncertainty of seismicity parameters based on the discussions and alternatives presented to me. Generally, I have made the interpretation that a and b are not correlated.

APPENDIX B

This appendix provides a complete account for the input data as it was used in the analysis.

The data is presented for each S-Expert independently in the following format:

Table Bi.1:	Information on the zonation given by Expert i.
Table Bi.2:	List of alternative zones or clusters of boundary zones.
Table Bi.3:	Seismicity data for Expert i.
Figure Bi.1:	Seismic zonation base map for Expert i.
Figure Bi.2:	Map of alternative seismic zonations to Expert i's base map.
Figure Bi.3:	Map of alternative seismic zonations to Expert i's base map.

In addition some comments are given when the above information was not sufficient to entirely define an Expert's input. This is the case for Expert 6 for example.

Table Bi.1: Gives the name of Expert i's zones as they appear in his maps, their area in km^2, and the confidence he associates with their existence as well as the name of the host zone (see Section 2 and Appendix C for details). The sequential index at the left of Table Bi.1 is a dummy index.

Table Bi.2: Provides an account of how the alternative zonation maps are constructed.

It gives the list of the zones to be replaced, the list of the replacing zones, and the name of the host zone.

For each cluster, the top line corresponds to the zones to be replaced and the bottom line identifies the replacing zones (OLD/NEW zones in cluster). BACK is the name of the host zone, and the two numbers specify the probability associated with each alternative.

For example, in the case of Expert 1, in the third cluster zone 4 and zone 5 have .6 probability of being in the zonation map, given that a zone exists at that location, and zone 25 has .4 probability of being there.

Table Bi.3: Provides the information necessary to define the earthquake frequency distribution within each zone. This includes for each seismic zone the best estimate, lower and upper bound for the a- and b-values, the upper magnitude cutoff. It also includes the type of variable used for the zone (magnitude or intensity), and the range of magnitude (or intensity values) for which the occurrence model is linear when the LLNL occurrence model is used. In addition, the very first line of the table indicates the total number of zones identified by the Expert, the self weights that the Expert gave for the four regions of the EUS (northeast, southeast, northcentral, and southcentral), and finally the type of correlation the Expert chose for the correlation between the a- and b-values.

Figure Bi.1: Gives the best estimate zonation map (BEM) for Expert i.

Figures Bi.2 and Bi.3: Give additional alternative zonation inputs for Expert i. In some cases the Expert has given entire alternative maps (e.g., Expert 1 or Expert 6) and in other cases the alternative maps provide additional input on alternative zones to replace zones of the BEM (e.g., Experts 5, 10, and 13). Experts 2, 3, 4, 7, 11, and 12 provided only a BEM. In these latter cases, the uncertainty in the zonation is modeled only by the probability of existence of each zone as shown in Table Bi.1.

Note that Table Bi.2 does not appear for the Experts who did not provide alternative zone boundaries (i.e., for Experts 2, 3, 4, 7, 11, and 12).

TABLE B1.1

INFORMATION ABOUT ZONES DEFINED
BY EXPERT 1

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 1	1.00		1024338.7
2	ZONE 2	.80	ZONE 1	604.8
3	ZONE 3	1.00		169056.3
4	ZONE 4	1.00		401420.2
5	ZONE 5	1.00		290133.9
6	ZONE 6	.70	ZONE 15	71043.9
7	ZONE 7	1.00		97266.4
8	ZONE 8	.50	ZONE 15	327614.4
9	ZONE 9	1.00		6132.0
10	ZONE 10	1.00		41607.4
11	ZONE 11	1.00		58103.1
12	ZONE 12	1.00		15237.1
13	ZONE 13	.60	ZONE 15	36601.6
14	ZONE 14	1.00		62768.8
15	ZONE 15	1.00		1655733.0
16	ZONE 16	.70	ZONE 15	132305.0
17	ZONE 17	.50	ZONE 15	396181.6
18	ZONE 18	.70	ZONE 15	100329.9
19	ZONE 19	.70	ZONE 15	238384.2
20	ZONE 20	1.00		60993.5

TABLE B1.1 (Cont.)

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
21	ZONE 21	.90	ZONE 22	16599.1
22	ZONE 22	1.00		539406.0
23	ZONE 23	1.00		1225269.9
24	ZONE 24	1.00		20911.5
25	ZONE 25	1.00		684252.7
26	ZONE 26A	1.00		22496.2
27	ZONE 26B	1.00		24833.5
28	ZONE 27	1.00		145872.2
29	ZONE 28	1.00		188165.7
30	ZONE 29	1.00		89116.7
31	ZONE 30	1.00		31795.2
32	ZONE 31	1.00		55853.7
33	ZONE 32	1.00		2540090.6
34	ZONE 33	1.00		25716.7
35	ZONE 34	1.00		4711.2
36	ZONE 35	1.00		5069.4
37	ZONE 36	1.00		4199.4
38	ZONE 37	1.00		97289.3
39	ZONE 38	1.00		288685.8
40	ZONE 39	1.00		232598.9

TABLE B1.2

EXPERT 1

LIST OF ALTERNATIVE ZONES OR CLUSTERS OF BOUNDARY ZONES

CLUSTER INDEX	WEIGHT	BACK	OLD/NEW ZONES IN CLUSTER				
1	.650	ZONE 15	ZONE 1	ZONE 2	ZONE 6	ZONE 7	ZONE 8
	.350		ZONE 23	ZONE 26	ZONE 28		
2	.650	ZONE 15	ZONE 3				
	.350		ZONE 26	ZONE 27			
3	.600	ZONE 15	ZONE 4	ZONE 5			
	.400		ZONE 25				
4	.700	ZONE 15	ZONE 10	ZONE 11	ZONE 12		
	.300		ZONE 30	ZONE 31			
5	.600	ZONE 15	ZONE 14				
	.400		ZONE 29				
6	.650	ZONE 1	ZONE 15	ZONE 16	ZONE 17	ZONE 18	ZONE 19
	.350		ZONE 32	ZONE 33	ZONE 34	ZONE 35	
7	.500	ZONE 22	ZONE 20				
	.500		ZONE 37				
8	.600		ZONE 21				

TABLE B1.2 (Cont.)

	.400	ZONE 36	
9	.500	ZONE 22	
	.500	ZONE 38	ZONE 39

TABLE B1.3

SEISMICITY DATA FOR EXPERT 1

NO. OF ZONES= 40 SELF WEIGHTS ARE 7.0 9.0 9.0 10.0 LLNL MODEL PARTIAL CORRELATION

SEQ. # 1 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 1
OCCURRENCE MODEL IN INTENSITY LINEAR RANGE OF (A-B*I) MODEL IS 4.00 9.45

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	9.5	9.3	9.5
A	2.680	2.600	2.940
B	-.600	-.640	-.590

SEQ. # 2 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 2
OCCURRENCE MODEL IN INTENSITY LINEAR RANGE OF (A-B*I) MODEL IS 4.00 10.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	10.0	9.5	10.5
A	1.870	1.660	2.070
B	-.490	-.490	-.480

SEQ. # 3 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 3
OCCURRENCE MODEL IN INTENSITY LINEAR RANGE OF (A-B*I) MODEL IS 4.00 8.80

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	8.8	8.5	9.0
A	2.604	2.374	3.144
B	-.630	-.750	-.590

SEQ. # 4 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 4
OCCURRENCE MODEL IN INTENSITY LINEAR RANGE OF (A-B*I) MODEL IS 4.00 9.10

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	9.1	8.9	9.5
A	3.874	3.244	4.784
B	-.750	-.870	-.640

SEQ. # 5 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 5
OCCURRENCE MODEL IN INTENSITY LINEAR RANGE OF (A-B*I) MODEL IS 4.00 9.80

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	9.8	9.1	10.2
A	2.350	2.070	3.250
B	-.540	-.690	-.500

*********** SEISMICITY DATA FOR EXPERT 1 **********

TABLE B1.3 (Cont.)

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****************************************************************************************************
SEQ. #  6     LOC IN REG NO  4                    ******** MAP ZONE NAME =ZONE  6
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      5.40

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                           5.4                           5.3                          5.7
    A                               4.180                         3.410                        4.520
    B                              -1.480                        -1.570                       -1.270
****************************************************************************************************
SEQ. #  7     LOC IN REG NO  4                    ******** MAP ZONE NAME =ZONE  7
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      5.40

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                           5.4                           5.3                          5.7
    A                               4.310                         3.540                        4.650
    B                              -1.480                        -1.570                       -1.270
****************************************************************************************************
SEQ. #  8     LOC IN REG NO  4                    ******** MAP ZONE NAME =ZONE  8
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      5.40

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                           5.4                           5.3                          5.7
    A                               4.840                         4.070                        5.180
    B                              -1.480                        -1.570                       -1.270
****************************************************************************************************
SEQ. #  9     LOC IN REG NO  4                    ******** MAP ZONE NAME =ZONE  9
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      7.50

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                           7.4                           7.2                          7.5
    A                               2.559                         2.419                        2.779
    B                               -.750                         -.810                        -.720
****************************************************************************************************
SEQ. # 10     LOC IN REG NO  4                    ******** MAP ZONE NAME =ZONE 10
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      7.10

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                           7.1                           6.9                          7.2
    A                               2.790                         2.740                        2.960
    B                               -.820                         -.870                        -.810
                          ***********  SEISMICITY DATA FOR EXPERT 1       **********
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TABLE B1.3 (Cont.)

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*****************************************************************************************************
SEQ. # 11     LOC IN REG NO  4                   ******** MAP ZONE NAME =ZONE 11
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        3.50       6.70

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           6.7                           6.5                            6.8
    A                               2.374                         2.124                          3.114
    B                               -.790                         -.940                          -.770
*****************************************************************************************************
SEQ. # 12     LOC IN REG NO  4                   ******** MAP ZONE NAME =ZONE 12
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        3.50       5.70

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           5.7                           5.5                            5.9
    A                               4.510                         3.390                          5.960
    B                              -1.320                        -1.630                         -1.080
*****************************************************************************************************
SEQ. # 13     LOC IN REG NO  4                   ******** MAP ZONE NAME =ZONE 13
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        3.50       6.00

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           6.0                           5.6                            6.2
    A                               4.460                         3.830                          5.880
    B                              -1.240                        -1.590                         -1.100
*****************************************************************************************************
SEQ. # 14     LOC IN REG NO  4                   ******** MAP ZONE NAME =ZONE 14
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        3.50       5.70

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           5.7                           5.5                            6.0
    A                               4.234                         3.434                          4.904
    B                              -1.270                        -1.440                         -1.080
*****************************************************************************************************
SEQ. # 15     LOC IN REG NO  3                   ******** MAP ZONE NAME =ZONE 15
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        3.50       5.80

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           5.8                           5.7                            6.0
    A                               5.614                         4.954                          6.254
    B                              -1.480                        -1.640                         -1.340
                         ***********  SEISMICITY DATA FOR EXPERT 1       **********
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TABLE B1.3 (Cont.)

SEQ. # 16 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 16
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.60

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.6	5.4	6.1
A	5.184	3.734	6.454
B	-1.450	-1.760	-1.110

SEQ. # 17 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 17
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.20

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.2	5.1	5.3
A	5.630	4.650	5.841
B	-1.670	-1.700	-1.410

SEQ. # 18 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 18
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.20

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.2	5.1	5.3
A	5.041	4.061	5.250
B	-1.670	-1.700	-1.410

SEQ. # 19 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 19
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 6.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	6.1	7.0
A	2.954	2.274	3.714
B	-.930	-1.110	-.760

SEQ. # 20 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 20
OCCURRENCE MODEL IN INTENSITY LINEAR RANGE OF (A-B*I) MODEL IS 4.00 10.10

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	10.1	9.8	10.4
A	2.014	1.900	2.234
B	-.500	-.530	-.470

*********** SEISMICITY DATA FOR EXPERT 1 **********

TABLE B1.3 (Cont.)

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**************************************************************************************************************
SEQ. # 21     LOC IN REG NO  1                        ******** MAP ZONE NAME =ZONE 21
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS        4.00      11.10
PARAMETER                    BEST ESTIMATE                     LOWER LIMIT                   UPPER LIMIT
UP MAG CO                        11.1                              10.7                          11.6
    A                            1.218                             .828                          1.548
    B                            -.380                             -.420                         -.330
**************************************************************************************************************
SEQ. # 22     LOC IN REG NO  1                        ******** MAP ZONE NAME =ZONE 22
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS        4.00      9.50
PARAMETER                    BEST ESTIMATE                     LOWER LIMIT                   UPPER LIMIT
UP MAG CO                        9.5                               9.1                           10.1
    A                            2.829                             1.999                         3.429
    B                            -.610                             -.710                         -.500
**************************************************************************************************************
SEQ. # 23     LOC IN REG NO  4                        ******** MAP ZONE NAME =ZONE 23
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS        4.00      8.70
PARAMETER                    BEST ESTIMATE                     LOWER LIMIT                   UPPER LIMIT
UP MAG CO                        8.7                               8.5                           8.9
    A                            3.000                             2.710                         3.260
    B                            -.690                             -.740                         -.640
**************************************************************************************************************
SEQ. # 24     LOC IN REG NO  4                        ******** MAP ZONE NAME =ZONE 24
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS        4.00      10.00
PARAMETER                    BEST ESTIMATE                     LOWER LIMIT                   UPPER LIMIT
UP MAG CO                        4.3                               3.8                           4.5
    A                            -5.000                            -6.000                        -5.000
    B                            -.500                             -5.000                        -.500
**************************************************************************************************************
SEQ. # 25     LOC IN REG NO  4                        ******** MAP ZONE NAME =ZONE 25
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS        4.00      9.90
PARAMETER                    BEST ESTIMATE                     LOWER LIMIT                   UPPER LIMIT
UP MAG CO                        9.9                               9.7                           10.3
    A                            3.830                             3.540                         4.370
    B                            -.690                             -.760                         -.630
                    ***********  SEISMICITY DATA FOR EXPERT 1        **********
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TABLE B.1.3 (Cont.)

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****************************************************************************************************
SEQ. # 26     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 26A
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF          (A-B*I)   MODEL IS        4.00     10.20

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          10.2                          9.8                           10.6
    A                              1.367                         1.197                         1.617
    B                              -.460                         -.500                         -.430
****************************************************************************************************
SEQ. # 27     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 27
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF          (A-B*I)   MODEL IS        4.00      8.70

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           8.7                          8.4                            8.8
    A                              2.720                         2.480                         3.240
    B                              -.660                         -.750                         -.620
****************************************************************************************************
SEQ. # 28     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 28
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF          (A-B*I)   MODEL IS        4.00      9.30

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           9.3                          9.0                            9.7
    A                              1.800                         1.500                         2.050
    B                              -.510                         -.560                         -.460
****************************************************************************************************
SEQ. # 29     LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 29
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF          (A-B*I)   MODEL IS        4.00      8.90

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           8.9                          8.3                            9.8
    A                              1.990                         1.360                         2.780
    B                              -.560                         -.700                         -.440
****************************************************************************************************
SEQ. # 30     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE 30
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF          (A-B*I)   MODEL IS        4.00      9.90

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           9.9                          9.5                           10.7
    A                              1.670                         1.180                         1.840
    B                              -.470                         -.510                         -.390
                           ***********  SEISMICITY DATA FOR EXPERT 1       **********
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TABLE B1.3 (Cont.)

```
****************************************************************************************************
SEQ. # 31     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 31
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      7.20

PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                         7.2                          7.0                          7.4
    A                             2.990                        2.790                        3.500
    B                             -.830                        -.940                        -.790
****************************************************************************************************
SEQ. # 32     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 32
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF      (A-B*I)   MODEL IS       4.00     10.20

PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                         10.2                         9.6                          11.2
    A                             2.920                        2.720                        3.700
    B                             -.610                        -.700                        -.510
****************************************************************************************************
SEQ. # 33     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 33
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF      (A-B*I)   MODEL IS       4.00     10.20

PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                         10.2                         9.6                          11.2
    A                             .920                         .720                         1.700
    B                             -.610                        -.700                        -.510
****************************************************************************************************
SEQ. # 34     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 34
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      7.20

PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                         7.2                          7.0                          7.4
    A                             1.340                        0.000                        1.620
    B                             -.600                        -.660                        -.540
****************************************************************************************************
SEQ. # 35     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 35
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF      (A-B*I)   MODEL IS       4.00     11.20

PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                         11.2                         9.7                          12.0
    A                             .471                         .181                         .901
    B                             -.280                        -.370                        -.230
                  ***********  SEISMICITY DATA FOR EXPERT 1       **********
```

TABLE B1.3 (Cont.)

```
*******************************************************************************************************
SEQ. # 36      LOC IN REG NO  1                  ******** MAP ZONE NAME =ZONE 36
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF          (A-B*I)   MODEL IS        4.00      11.40

PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                           11.4                          11.0                          12.0
    A                                .858                          .478                         1.008
    B                               -.340                         -.360                         -.280
*******************************************************************************************************
SEQ. # 37      LOC IN REG NO  1                  ******** MAP ZONE NAME =ZONE 37
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF          (A-B*I)   MODEL IS        4.00      10.80

PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                           10.8                          10.3                          11.2
    A                               1.820                         1.590                         2.030
    B                               -.440                         -.490                         -.410
*******************************************************************************************************
SEQ. # 38      LOC IN REG NO  1                  ******** MAP ZONE NAME =ZONE 38
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF          (A-B*I)   MODEL IS        4.00      10.00

PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                           10.0                           9.5                          10.3
    A                               2.330                         2.180                         2.740
    B                               -.530                         -.610                         -.500
*******************************************************************************************************
SEQ. # 39      LOC IN REG NO  1                  ******** MAP ZONE NAME =ZONE 39
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF          (A-B*I)   MODEL IS        4.00       9.40

PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                            9.4                           9.1                           9.8
    A                               2.260                         1.890                         2.540
    B                               -.560                         -.610                         -.500
*******************************************************************************************************
SEQ. # 40      LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 26B
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF          (A-B*I)   MODEL IS        4.00      10.20

PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                           10.2                           9.8                          10.6
    A                               1.410                         1.240                         1.660
    B                               -.460                         -.500                         -.430
*******************************************************************************************************
                   ********* END OF SEISMICITY DATA FOR EXPERT 1     ZONES *****

    EXPERT'S RELATION BETWEEN I(MAX) & MB IS
    I(MAX)=  2.16*MB -4.40
```

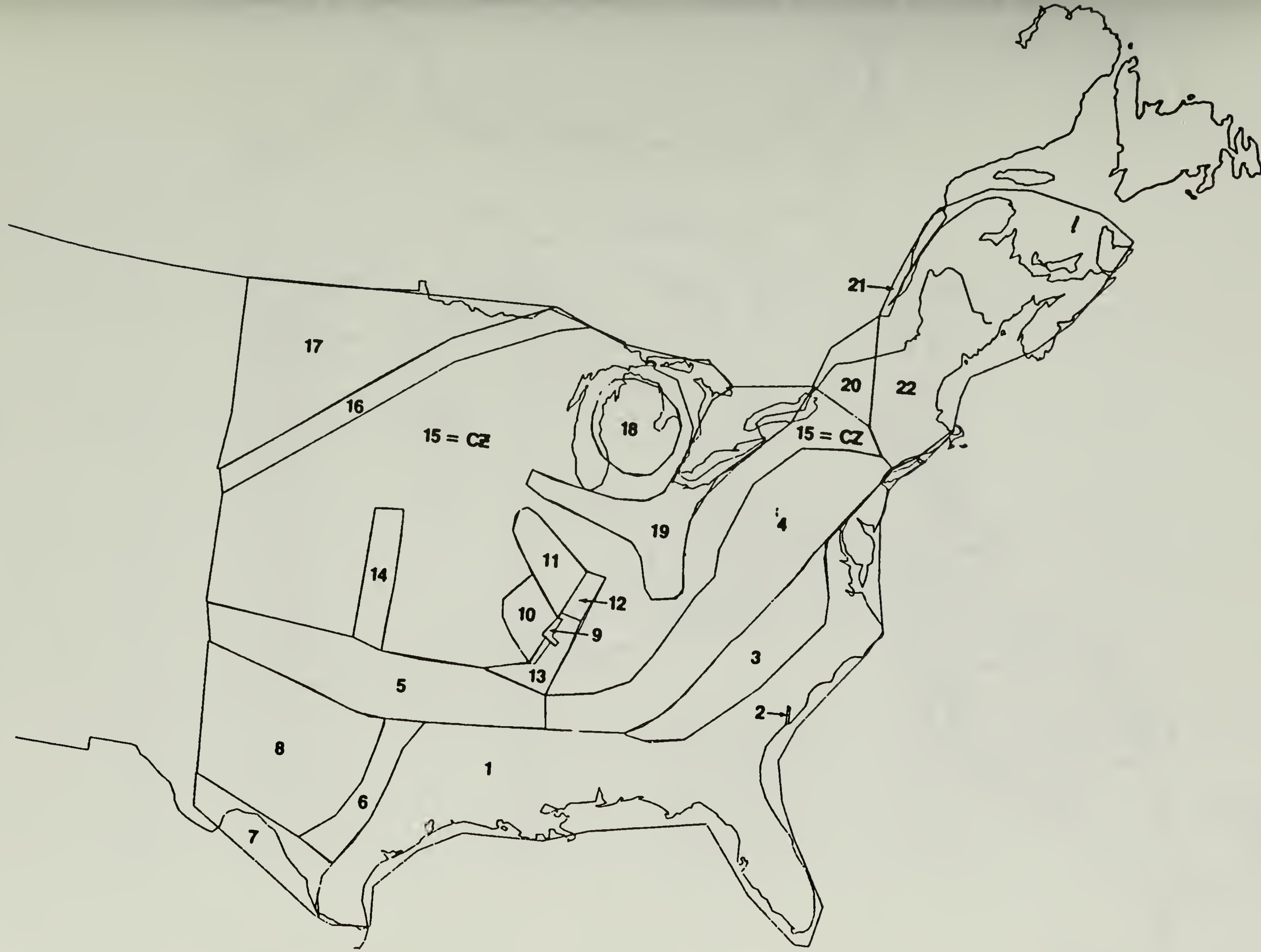

Figure B1.1 Seismic zonation base map for Expert 1.

Figure B1.2 Map of alternative seismic zonation to Expert 1's base map.

TABLE B2.1

INFORMATION ABOUT ZONES DEFINED
BY EXPERT 2

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 1	1.00	COMP. ZONE	1499.2
2	ZONE 2	1.00		1227.1
3	ZONE 3	1.00		4620.5
4	ZONE 4	.90	COMP. ZONE	34145.2
5	ZONE 5	.60	ZONE 6	15112.7
6	ZONE 7	.60	ZONE 4	4578.4
7	ZONE 8	.50	ZONE 6	2905.6
8	ZONE 12	.50	COMP. ZONE	42237.0
9	ZONE 6	.60	COMP. ZONE	210829.6
10	ZONE 13	.80	COMP. ZONE	288765.3
11	ZONE 14	.50	COMP. ZONE	6289.7
12	ZONE 15	.50	COMP. ZONE	65489.2
13	ZONE 18	1.00		40554.7
14	ZONE 19	1.00		36357.7
15	ZONE 20	.80	COMP. ZONE	65814.7
16	ZONE 21	.50	COMP. ZONE	54632.7
17	ZONE 22	.50	COMP. ZONE	11723.1
18	ZONE 27	.70	COMP. ZONE	275995.6
19	ZONE 28	.60	COMP. ZONE	81275.5
20	ZONE 29	.50	COMP. ZONE	102369.6

TABLE B2.1 (Cont.)

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
21	ZONE 30	.70	COMP. ZONE	19022.8
22	ZONE 31	.70	COMP. ZONE	249106.0
23	ZONE 32	.70	COMP. ZONE	74153.1
24	COMP. ZONE	1.00		7661198.2
25	ZONE 9	.30	ZONE 6	377.1
26	ZONE 10	.40	ZONE 6	36329.1
27	ZONE 11	.40	COMP. ZONE	92280.4
28	ZONE 16	.30	COMP. ZONE	45017.3
29	ZONE 17	.30	COMP. ZONE	77022.7
30	ZONE 23	.30	COMP. ZONE	62498.2
31	ZONE 24	.40	COMP. ZONE	17985.6
32	ZONE 25	.30	COMP. ZONE	17235.6
33	ZONE 26	.40	COMP. ZONE	39212.8
34	ZONE 33	.40	COMP. ZONE	34581.7

TABLE B2.3

SEISMICITY DATA FOR EXPERT 2

NO. OF ZONES= 34 SELF WEIGHTS ARE 3.0 6.0 9.0 10.0 LLNL MODEL NO CORRELATION

SEQ. # 1 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 1
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 2.00 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.0	6.0	7.5
A	2.584	2.474	2.994
B	-.995	-1.240	-.884

SEQ. # 2 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 2
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 2.00 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	5.5	7.0
A	2.474	2.194	6.534
B	-.977	-3.270	-.789

SEQ. # 3 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 3
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 2.00 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.5	7.0
A	1.492	1.482	2.622
B	-.819	-1.370	-.527

SEQ. # 4 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 4
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 1.70 4.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	5.5	6.8
A	2.434	2.344	2.584
B	-.906	-1.170	-.906

SEQ. # 5 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 5
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 2.10 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.5	6.3
A	2.382	2.312	4.702
B	-.553	-1.640	-.494

*********** SEISMICITY DATA FOR EXPERT 2 **********

TABLE B2.3 (Cont.)

****

SEQ. # 6 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 6
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 1.70 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	5.5	6.0
A	2.294	2.144	2.314
B	-.883	-.899	-.841

****

SEQ. # 7 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 7
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 1.50 4.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	5.5	7.0
A	2.612	2.612	2.902
B	-1.030	-1.200	-.965

****

SEQ. # 8 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 8
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 4.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.5	5.0	5.8
A	2.922	2.822	3.052
B	-1.940	-1.950	-1.900

****

SEQ. # 9 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 9
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 2.00 4.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.3	5.0	5.5
A	5.272	4.812	6.112
B	-2.500	-2.860	-2.370

****

SEQ. # 10 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 10
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 4.00 6.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	5.5	6.8
A	3.500	3.000	4.000
B	-1.000	-1.200	-.800

*********** SEISMICITY DATA FOR EXPERT 2 **********

TABLE B2.3 (Cont.)

SEQ. # 11 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 11
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.0	6.3
A	2.011	1.171	3.171
B	-.874	-1.210	-.625

SEQ. # 12 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 12
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.5	6.5
A	4.899	1.249	4.899
B	-1.330	-1.500	-.577

SEQ. # 13 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 13
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 4.00 5.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.5	6.3
A	3.317	2.971	4.171
B	-1.020	-1.200	-.800

SEQ. # 14 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 14
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 4.00 5.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.5	4.5	5.8
A	2.301	1.301	3.101
B	-1.000	-1.200	-.800

SEQ. # 15 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 15
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 4.00 5.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.5	6.5
A	2.959	.959	3.459
B	-1.000	-1.200	-.800

*********** SEISMICITY DATA FOR EXPERT 2 **********

TABLE B2.3 (Cont.)

SEQ. # 16 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 16
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.80 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.0	6.3
A	2.790	2.570	3.170
B	-.944	-1.200	-.800

SEQ. # 17 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 17
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 4.00 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	5.5	6.8
A	2.576	2.076	3.076
B	-1.000	-1.200	-.340

SEQ. # 18 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 18
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 7.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.8	7.5	8.0
A	2.246	1.890	2.770
B	-.621	-1.000	-.522

SEQ. # 19 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 19
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 6.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	5.5	7.0
A	2.837	2.624	3.024
B	-.912	-1.000	-.800

SEQ. # 20 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 20
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 6.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	5.8	7.3
A	2.060	1.975	2.266
B	-.653	-.759	-.634

*********** SEISMICITY DATA FOR EXPERT 2 **********

TABLE B2.3 (Cont.)

SEQ. # 21 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 21
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 4.00 5.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.5	6.5
A	2.529	2.180	2.880
B	-.923	-.959	-.887

SEQ. # 22 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 22
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 4.00 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.3	5.5	6.5
A	2.597	2.097	3.097
B	-1.000	-1.200	-.800

SEQ. # 23 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 23
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.5	5.3	6.0
A	2.700	2.200	3.200
B	-1.000	-1.200	-.800

SEQ. # 24 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 24
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 4.00 5.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	6.0	6.8
A	3.914	2.200	4.000
B	-1.118	-1.300	-.790

SEQ. # 25 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 25
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 4.00 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.5	6.3
A	2.501	2.001	3.001
B	-1.000	-1.200	-.800

*********** SEISMICITY DATA FOR EXPERT 2 **********

TABLE B2.3 (Cont.)

```
****************************************************************************************************
SEQ. # 26     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 26
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        4.00      5.50
PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                              6.0                          5.5                           6.3
    A                                  5.301                        3.921                         5.421
    B                                 -1.470                       -1.500                        -1.000
****************************************************************************************************
SEQ. # 27     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 27
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        4.00      6.00
PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                              6.5                          6.0                           7.0
    A                                  4.167                        2.947                         5.387
    B                                 -1.060                       -1.226                         -.901
****************************************************************************************************
SEQ. # 28     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 28
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        4.00      5.50
PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                              6.3                          6.0                           6.5
    A                                  3.229                        2.989                         3.479
    B                                  -.911                        -.929                         -.892
****************************************************************************************************
SEQ. # 29     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 29
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        4.00      5.50
PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                              6.5                          6.0                           6.8
    A                                  2.830                        2.500                         3.100
    B                                  -.876                       -1.100                         -.700
****************************************************************************************************
SEQ. # 30     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 30
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        4.00      6.50
PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                              7.5                          7.0                           7.8
    A                                  2.530                        2.300                         2.700
    B                                  -.671                        -.800                         -.500
                        ***********  SEISMICITY DATA FOR EXPERT 2        **********
```

TABLE B2.3 (Cont.)

```
*************************************************************************************
SEQ. # 31     LOC IN REG NO  1                 ******** MAP ZONE NAME =ZONE 31
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        4.00       6.00

PARAMETER                   BEST ESTIMATE                    LOWER LIMIT                    UPPER LIMIT
UP MAG CO                        6.5                             6.3                            7.0
    A                            3.965                           3.845                          4.045
    B                           -1.030                          -1.200                          -.800
*************************************************************************************
SEQ. # 32     LOC IN REG NO  1                 ******** MAP ZONE NAME =ZONE 32
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        4.00       6.00

PARAMETER                   BEST ESTIMATE                    LOWER LIMIT                    UPPER LIMIT
UP MAG CO                        7.8                             7.5                            8.0
    A                            2.453                           2.399                          2.599
    B                            -.685                           -.800                          -.500
*************************************************************************************
SEQ. # 33     LOC IN REG NO  3                 ******** MAP ZONE NAME =ZONE 33
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        4.00       6.00

PARAMETER                   BEST ESTIMATE                    LOWER LIMIT                    UPPER LIMIT
UP MAG CO                        6.5                             6.3                            7.0
    A                            3.224                           2.844                          3.604
    B                            -.970                          -1.000                          -.950
*************************************************************************************
SEQ. # 34     LOC IN REG NO  2                 ******** MAP ZONE NAME =34-C.Z.
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        4.00       6.00

PARAMETER                   BEST ESTIMATE                    LOWER LIMIT                    UPPER LIMIT
UP MAG CO                        7.3                             6.5                            7.5
    A                            4.660                           4.520                          4.920
    B                           -1.100                          -1.250                          -.900
*************************************************************************************
               ********* END OF SEISMICITY DATA FOR EXPERT 2     ZONES *****

    EXPERT'S RELATION BETWEEN I(MAX) & MB IS
    I(MAX)=  2.00*MB -3.50
```

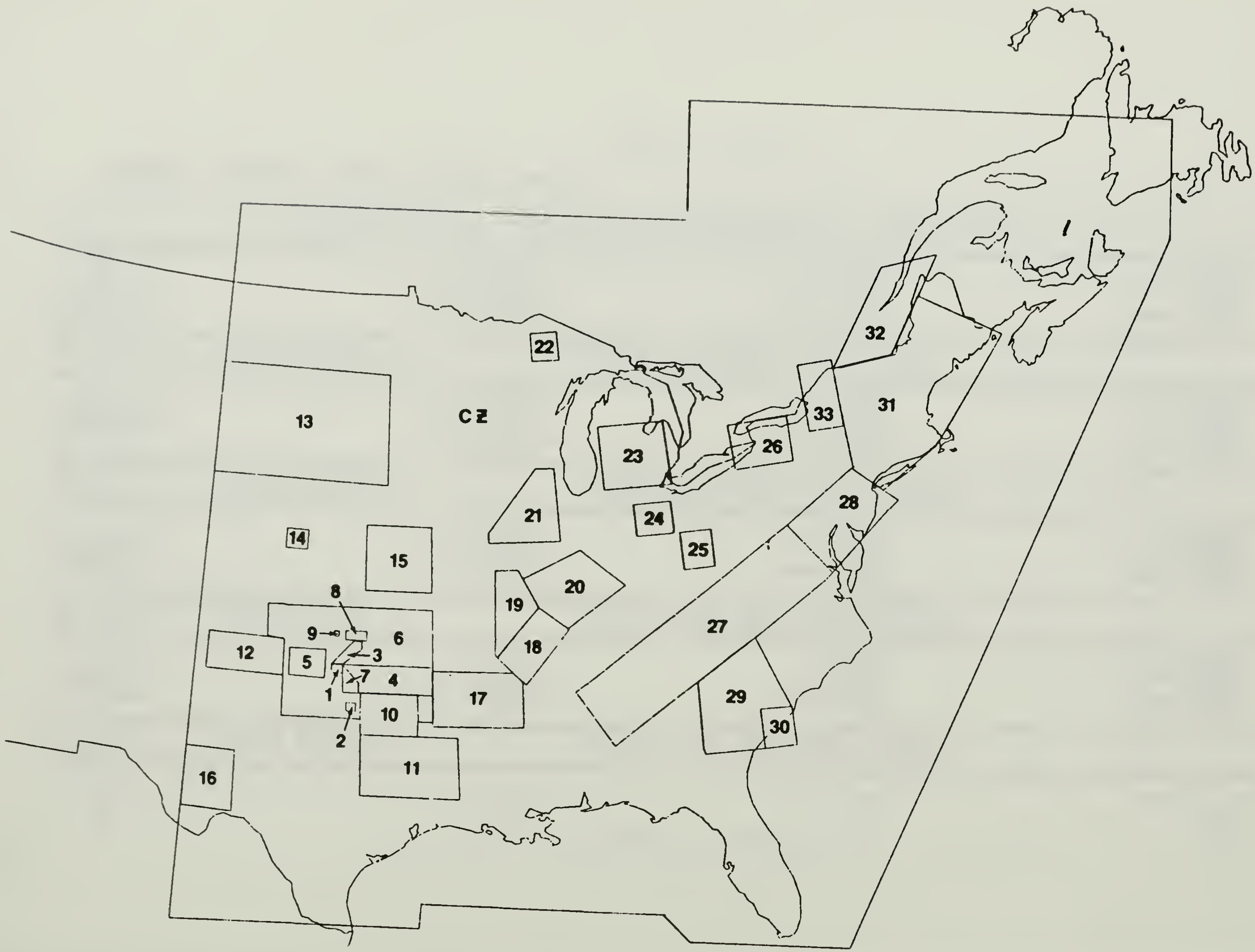

Figure B2.1 Seismic zonation base map for Expert 2.

TABLE B3.1

INFORMATION ABOUT ZONES DEFINED
BY EXPERT 3

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 3	.90	ZONE 2	60942.1
2	ZONE 2	.90	COMP. ZONE	680814.6
3	ZONE 4	.80	ZONE 2	288240.1
4	ZONE 5	.90	ZONE 4	291855.6
5	ZONE 6	1.00		21777.8
6	ZONE 7	.70	COMP. ZONE	143326.5
7	ZONE 9	1.00		10365.6
8	ZONE 8	.80	ZONE 8A	102423.0
9	ZONE 8A	.60	COMP. ZONE	265359.6
10	ZONE 10	.60	COMP. ZONE	530155.8
11	ZONE 11	.70	ZONE 15	328201.9
12	ZONE 13	.90	ZONE 12	50162.8
13	ZONE 12	.90	ZONE 16	198257.1
14	ZONE 14	.70	ZONE 16	284787.2
15	ZONE 15	.70	ZONE 16	246913.8
16	ZONE 16	.60	COMP. ZONE	1034528.0
17	COMP. ZONE	1.00		5627787.9

TABLE B3.3

SEISMICITY DATA FOR EXPERT 3

NO. OF ZONES= 17 SELF WEIGHTS ARE 5.0 10.0 5.0 5.0 LLNL MODEL NO CORRELATION

SEQ. # 1 LOC IN REG NO 3 ******** MAP ZONE NAME =CZ = ZONE 1
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.5	5.3	5.8
A	4.390	4.120	4.660
B	-1.150	-1.350	-1.000

SEQ. # 2 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 2
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 6.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.4	6.3	7.0
A	4.860	4.600	5.120
B	-1.200	-1.540	-.860

SEQ. # 3 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 3
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.70

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.0	6.8	7.3
A	2.720	2.610	2.830
B	-.820	-1.070	-.800

SEQ. # 4 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 4
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.3	6.0	7.0
A	4.310	4.100	4.520
B	-1.150	-1.500	-.800

SEQ. # 5 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 5
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.2	6.0	7.0
A	4.550	4.350	4.750
B	-1.190	-1.430	-.950

TABLE B3.3 (Cont.)

****

SEQ. # 6 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 6
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.5	6.5
A	3.310	3.160	3.460
B	-1.100	-1.270	-.940

****

SEQ. # 7 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 7
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	5.2	6.3
A	4.010	3.760	4.260
B	-1.210	-1.420	-1.000

****

SEQ. # 8 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 8
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 4.60

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.4	6.0	6.8
A	3.370	3.220	3.520
B	-1.190	-1.310	-.970

****

SEQ. # 9 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 9
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.8	6.5	7.0
A	2.600	2.390	3.310
B	-.890	-1.100	-.800

****

SEQ. # 10 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 10
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 4.70

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	5.4	6.2
A	3.590	3.390	3.790
B	-1.090	-1.370	-.810

*********** SEISMICITY DATA FOR EXPERT 3 **********

TABLE B3.3 (Cont.)

```
***********************************************************************************************************
SEQ. # 11     LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 11
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75      5.50
PARAMETER                        BEST ESTIMATE               LOWER LIMIT                       UPPER LIMIT
UP MAG CO                            6.0                        5.8                                6.3
     A                               3.800                      3.630                              3.970
     B                              -1.040                     -1.280                              -.900
***********************************************************************************************************
SEQ. # 12     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE 12
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75      5.50
PARAMETER                        BEST ESTIMATE               LOWER LIMIT                       UPPER LIMIT
UP MAG CO                            6.8                        6.5                                7.3
     A                               3.450                      3.300                              3.600
     B                               -.950                     -1.020                              -.880
***********************************************************************************************************
SEQ. # 13     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE 13
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75      6.00
PARAMETER                        BEST ESTIMATE               LOWER LIMIT                       UPPER LIMIT
UP MAG CO                            7.5                        7.3                                7.8
     A                               4.500                      4.100                              4.800
     B                              -1.140                     -1.240                             -1.040
***********************************************************************************************************
SEQ. # 14     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE 14
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75      5.75
PARAMETER                        BEST ESTIMATE               LOWER LIMIT                       UPPER LIMIT
UP MAG CO                            6.0                        5.8                                7.0
     A                               3.870                      3.720                              4.020
     B                              -1.090                     -1.300                              -.880
***********************************************************************************************************
SEQ. # 15     LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 15
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75      5.00
PARAMETER                        BEST ESTIMATE               LOWER LIMIT                       UPPER LIMIT
UP MAG CO                            5.8                        5.5                                6.3
     A                               3.590                      3.410                              3.770
     B                              -1.140                     -1.380                              -.900
                           ***********  SEISMICITY DATA FOR EXPERT 3        **********
```

TABLE B3.3 (Cont.)

```
****************************************************************************************************
SEQ. # 16     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 16
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       5.00

PARAMETER                         BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                             6.0                            5.5                           6.5
    A                                 4.550                          4.350                         4.750
    B                                -1.190                         -1.390                         -.990
****************************************************************************************************
SEQ. # 17     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 8A
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       5.20

PARAMETER                         BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                             6.2                            6.0                           6.5
    A                                 3.440                          3.240                         3.640
    B                                -1.110                         -1.340                         -.880
****************************************************************************************************
                    ********* END OF SEISMICITY DATA FOR EXPERT 3     ZONES *****

     EXPERT'S RELATION BETWEEN I(MAX) & MB IS
     I(MAX)=  2.00*MB -3.50
```

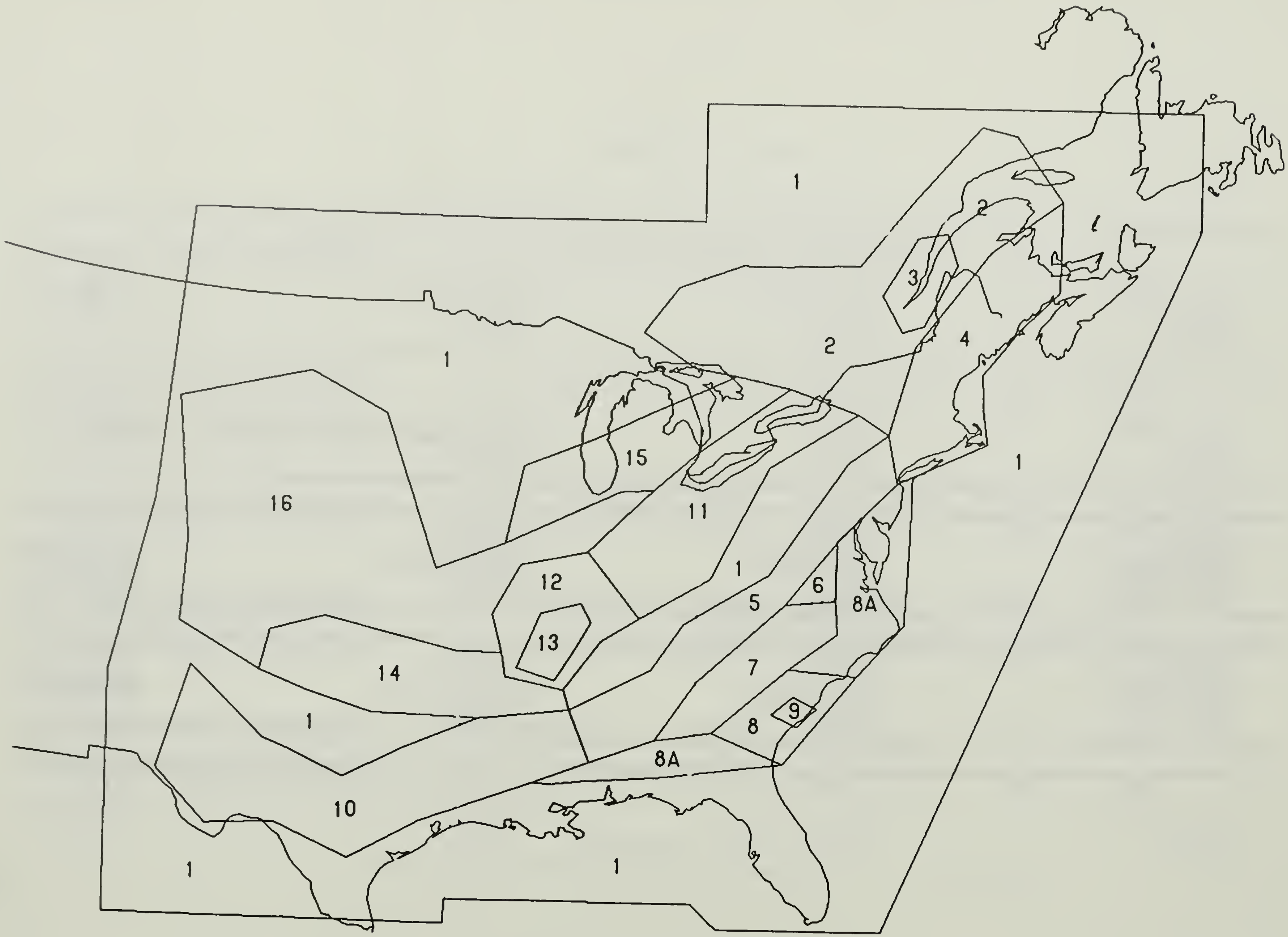

Figure B3.1 Seismic zonation base map for Expert 3.

TABLE B4.1

INFORMATION ABOUT ZONES DEFINED
BY EXPERT 4

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 1	.50	ZONE 13	71964.5
2	ZONE 2	.50	ZONE 13	93833.2
3	ZONE 3	1.00		42569.3
4	ZONE 4	1.00		19943.8
5	ZONE 5	1.00		58665.7
6	ZONE 6	.75	ZONE 13	62354.7
7	ZONE 7	.75	ZONE 13	7296.9
8	ZONE 26	.75	ZONE 8	5870.3
9	ZONE 27	.50	ZONE 13	90055.7
10	ZONE 28	1.00		40603.8
11	ZONE 8	.50	ZONE 11	113972.0
12	ZONE 9	.75	ZONE 11	83776.7
13	ZONE 10	1.00		25207.8
14	ZONE 11	1.00		126962.7
15	ZONE 12	1.00		103436.5
16	ZONE 14	1.00		10053.6
17	ZONE 15	1.00		25217.9
18	ZONE 16	1.00		88786.6
19	ZONE 17	1.00		10357.4
20	ZONE 13	1.00		1424511.5

TABLE B4.1 (Cont.)

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
21	ZONE 18	1.00		29927.2
22	ZONE 20	1.00		123754.6
23	ZONE 19	1.00		14524.1
24	ZONE 21	1.00		51250.8
25	ZONE 22	.75	COMP. ZONE	25012.1
26	ZONE 23	.75	ZONE 13	55186.7
27	ZONE 25	.75	ZONE 13	1460649.6
28	COMP. ZONE	1.00		4267241.5

TABLE B4.3

SEISMICITY DATA FOR EXPERT 4

```
NO. OF ZONES= 28     SELF WEIGHTS ARE  8.5  6.0  7.0  9.0   LLNL MODEL             FULL    CORRELATION
******************************************************************************************************
SEQ. #  1     LOC IN REG NO  4              ******** MAP ZONE NAME =ZONE  1
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75      6.10

PARAMETER                      BEST ESTIMATE                LOWER LIMIT                   UPPER LIMIT
UP MAG CO                            6.1                         5.8                            6.3
    A                              2.840                       2.770                          2.910
    B                              -.920                       -.970                          -.870
******************************************************************************************************
SEQ. #  2     LOC IN REG NO  4              ******** MAP ZONE NAME =ZONE  2
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75      5.60

PARAMETER                      BEST ESTIMATE                LOWER LIMIT                   UPPER LIMIT
UP MAG CO                            5.6                         5.5                            5.7
    A                              2.370                       2.295                          2.450
    B                              -.920                       -.970                          -.870
******************************************************************************************************
SEQ. #  3     LOC IN REG NO  4              ******** MAP ZONE NAME =ZONE  3
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75      6.60

PARAMETER                      BEST ESTIMATE                LOWER LIMIT                   UPPER LIMIT
UP MAG CO                            6.4                         6.0                            6.6
    A                              3.110                       3.040                          3.190
    B                              -.920                       -.970                          -.870
******************************************************************************************************
SEQ. #  4     LOC IN REG NO  4              ******** MAP ZONE NAME =ZONE  4
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75      7.50

PARAMETER                      BEST ESTIMATE                LOWER LIMIT                   UPPER LIMIT
UP MAG CO                            7.5                         7.4                            7.7
    A                              4.130                       4.055                          4.200
    B                              -.920                       -.970                          -.870
******************************************************************************************************
SEQ. #  5     LOC IN REG NO  4              ******** MAP ZONE NAME =ZONE  5
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75      6.50

PARAMETER                      BEST ESTIMATE                LOWER LIMIT                   UPPER LIMIT
UP MAG CO                            6.5                         6.2                            6.8
    A                              3.210                       3.130                          3.280
    B                              -.920                       -.970                          -.870
                          ***********  SEISMICITY DATA FOR EXPERT 4       **********
```

TABLE B4.3 (Cont.)

```
*******************************************************************************************
SEQ. #  6     LOC IN REG NO  3                    ******** MAP ZONE NAME =ZONE  6
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75      6.00

PARAMETER                        BEST ESTIMATE                LOWER LIMIT                    UPPER LIMIT
UP MAG CO                             6.0                          5.8                             6.1
   A                                2.750                        2.680                           2.810
   B                                -.920                        -.970                           -.870
*******************************************************************************************
SEQ. #  7     LOC IN REG NO  3                    ******** MAP ZONE NAME =ZONE  7
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75      6.00

PARAMETER                        BEST ESTIMATE                LOWER LIMIT                    UPPER LIMIT
UP MAG CO                             6.0                          5.5                             6.2
   A                                2.750                        2.680                           2.810
   B                                -.920                        -.970                           -.870
*******************************************************************************************
SEQ. #  8     LOC IN REG NO  2                    ******** MAP ZONE NAME =ZONE  8
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75      6.20

PARAMETER                        BEST ESTIMATE                LOWER LIMIT                    UPPER LIMIT
UP MAG CO                             6.2                          5.5                             6.3
   A                                2.940                        2.870                           3.010
   B                                -.920                       -1.100                           -.700
*******************************************************************************************
SEQ. #  9     LOC IN REG NO  2                    ******** MAP ZONE NAME =ZONE  9
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75      6.20

PARAMETER                        BEST ESTIMATE                LOWER LIMIT                    UPPER LIMIT
UP MAG CO                             6.2                          5.6                             6.3
   A                                2.940                        2.870                           3.010
   B                                -.920                       -1.100                           -.700
*******************************************************************************************
SEQ. # 10     LOC IN REG NO  2                    ******** MAP ZONE NAME =ZONE 10
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75      6.80

PARAMETER                        BEST ESTIMATE                LOWER LIMIT                    UPPER LIMIT
UP MAG CO                             6.8                          6.7                             7.0
   A                                3.480                        3.410                           3.560
   B                                -.920                       -1.100                           -.700
                      ***********  SEISMICITY DATA FOR EXPERT 4      **********
```

TABLE B4.3 (Cont.)

```
*********************************************************************************************
SEQ. # 11     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 11
OCCURRENCE MODEL IN MAGNITUDE    LINEAR RANGE OF     (A-B*M)   MODEL IS      3.75     5.70

PARAMETER                   BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                       5.7                           5.5                         5.8
    A                           2.470                         2.400                       2.530
    B                           -.920                        -1.100                       -.700
*********************************************************************************************
SEQ. # 12     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 12
OCCURRENCE MODEL IN MAGNITUDE    LINEAR RANGE OF     (A-B*M)   MODEL IS      3.75     6.00

PARAMETER                   BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                       5.9                           5.5                         6.0
    A                           2.660                         2.600                       2.730
    B                           -.920                        -1.100                       -.700
*********************************************************************************************
SEQ. # 13     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 13 = CENTRAL CZ
OCCURRENCE MODEL IN MAGNITUDE    LINEAR RANGE OF     (A-B*M)   MODEL IS      3.75     5.50

PARAMETER                   BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                       5.5                           5.4                         5.7
    A                           2.290                         2.230                       2.350
    B                           -.920                         -.970                       -.870
*********************************************************************************************
SEQ. # 14     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 14
OCCURRENCE MODEL IN MAGNITUDE    LINEAR RANGE OF     (A-B*M)   MODEL IS      3.75     5.60

PARAMETER                   BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                       5.6                           5.5                         5.8
    A                           2.380                         2.300                       2.450
    B                           -.920                         -.970                       -.870
*********************************************************************************************
SEQ. # 15     LOC IN REG NO  1                ******** MAP ZONE NAME =ZONE 15
OCCURRENCE MODEL IN MAGNITUDE    LINEAR RANGE OF     (A-B*M)   MODEL IS      3.75     5.60

PARAMETER                   BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                       5.6                           5.5                         5.8
    A                           2.370                         2.300                       2.450
    B                           -.920                        -1.100                       -.700
                         ***********  SEISMICITY DATA FOR EXPERT 4      **********
```

TABLE B4.3 (Cont.)

```
*****************************************************************************************************
SEQ. # 16      LOC IN REG NO  1                      ******** MAP ZONE NAME =ZONE 16
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       6.80

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          6.7                            6.3                            6.8
    A                              3.390                          3.200                          3.470
    B                              -.920                          -.970                          -.870
*****************************************************************************************************
SEQ. # 17      LOC IN REG NO  1                      ******** MAP ZONE NAME =ZONE 17
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       5.50

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          5.5                            5.5                            5.6
    A                              2.290                          2.230                          2.350
    B                              -.920                          -1.100                         -.700
*****************************************************************************************************
SEQ. # 18      LOC IN REG NO  1                      ******** MAP ZONE NAME =ZONE 18
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       6.30

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          6.3                            6.0                            6.4
    A                              3.020                          2.960                          3.090
    B                              -.920                          -.970                          -.870
*****************************************************************************************************
SEQ. # 19      LOC IN REG NO  1                      ******** MAP ZONE NAME =ZONE 19
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       6.70

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          6.7                            6.5                            6.9
    A                              3.390                          3.320                          3.470
    B                              -.920                          -.970                          -.870
*****************************************************************************************************
SEQ. # 20      LOC IN REG NO  1                      ******** MAP ZONE NAME =ZONE 20
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       6.50

PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          6.5                            6.3                            6.7
    A                              3.210                          3.130                          3.280
    B                              -.920                          -.970                          -.870
                         ***********  SEISMICITY DATA FOR EXPERT 4       **********
```

TABLE B4.3 (Cont.)

****

SEQ. # 21 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 21
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 6.10

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.1	5.9	6.3
A	2.840	2.770	2.910
B	-.920	-1.100	-.700

****

SEQ. # 22 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 22
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 7.20

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.2	7.0	7.4
A	3.850	3.780	3.930
B	-.920	-1.100	-.700

****

SEQ. # 23 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 23
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.60

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.6	5.4	5.8
A	2.370	2.300	2.450
B	-.920	-.970	-.870

****

SEQ. # 24 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 25
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.5	5.3	5.7
A	2.290	2.230	2.350
B	-.920	-.970	-.870

****

SEQ. # 25 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 26
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 6.10

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.1	5.9	6.3
A	2.840	2.770	2.910
B	-.920	-1.100	-.700

*********** SEISMICITY DATA FOR EXPERT 4 **********

TABLE B4.3 (Cont.)

```
**********************************************************************************************************
SEQ. # 26     LOC IN REG NO  3                    ******** MAP ZONE NAME =CZ PERIPHERY
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75       5.50

PARAMETER                       BEST ESTIMATE                    LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           5.5                              5.3                            5.7
    A                               2.590                            2.000                          3.130
    B                               -.920                            -.970                          -.870
**********************************************************************************************************
SEQ. # 27     LOC IN REG NO  3                    ******** MAP ZONE NAME =ZONE 27
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75       6.00

PARAMETER                       BEST ESTIMATE                    LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           6.0                              5.5                            6.2
    A                               2.750                            2.680                          2.810
    B                               -.920                            -.970                          -.870
**********************************************************************************************************
SEQ. # 28     LOC IN REG NO  3                    ******** MAP ZONE NAME =ZONE 28
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75       6.00

PARAMETER                       BEST ESTIMATE                    LOWER LIMIT                    UPPER LIMIT
UP MAG CO                           6.0                              5.5                            6.2
    A                               2.750                            2.680                          2.810
    B                               -.920                            -.970                          -.870
**********************************************************************************************************
                  ********* END OF SEISMICITY DATA FOR EXPERT 4     ZONES *****

    EXPERT'S RELATION BETWEEN I(MAX) & MB IS
    I(MAX)=  2.00*MB -3.50
```

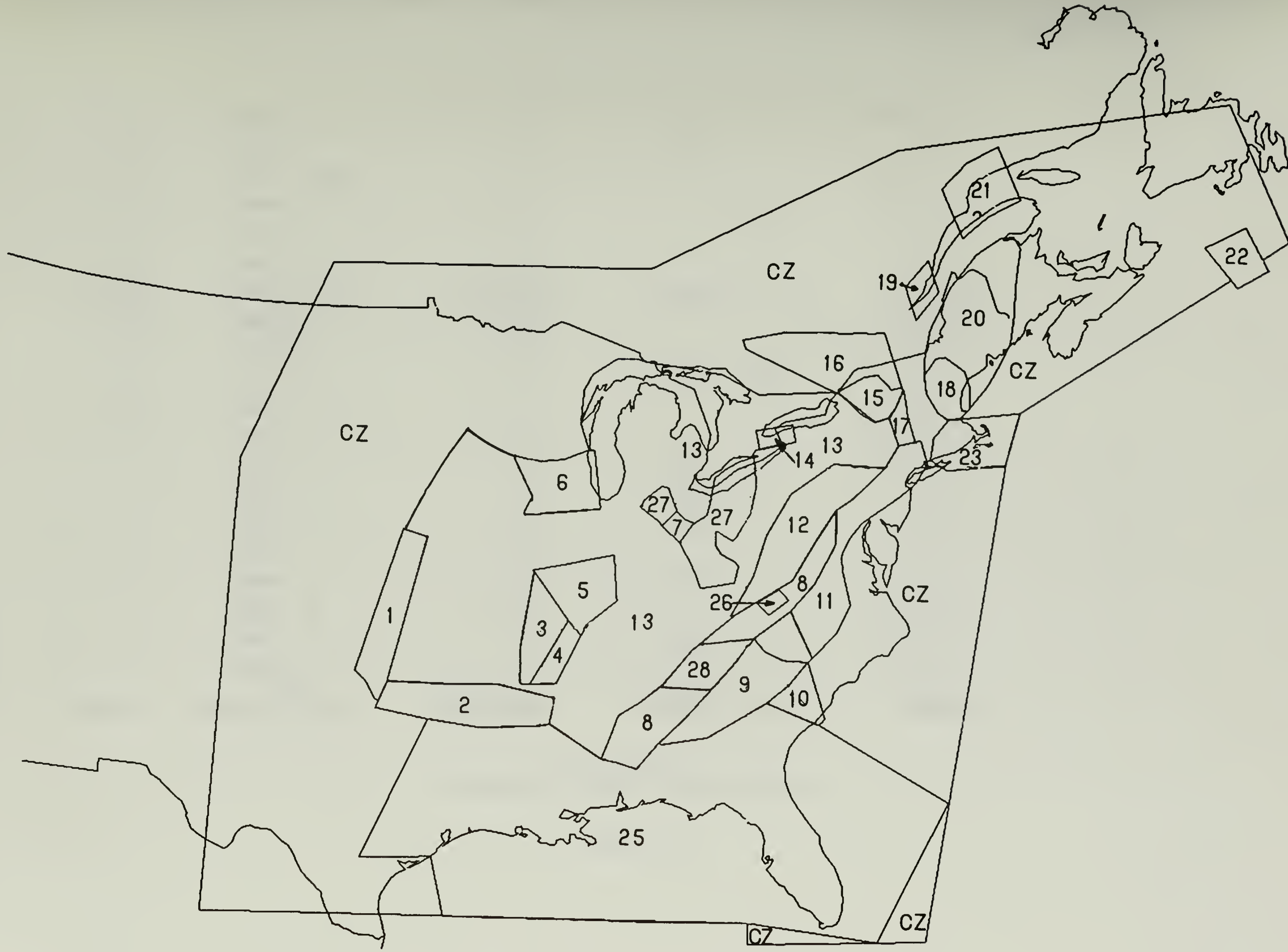

Figure B4.1 Seismic zonation base map for Expert 4.

TABLE B5.1

INFORMATION ABOUT ZONES DEFINED
BY EXPERT 5

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 1	1.00		633537.8
2	ZONE 3	.60	ZONE 4	131244.7
3	ZONE 4	1.00		541043.0
4	ZONE 6	.50	ZONE 5	2078.1
5	ZONE 5	1.00		29686.0
6	ZONE 8	.70	ZONE 1	428587.4
7	ZONE 9	.80	ZONE 8	17532.1
8	ZONE 10	.80	ZONE 1	254857.0
9	ZONE 11	1.00		322336.2
10	ZONE 12	1.00		27087.3
11	ZONE 13	.50	COMP. ZONE	33914.2
12	ZONE 15	1.00		23605.7
13	ZONE 14	1.00		164695.9
14	ZONE 16	1.00		392333.9
15	ZONE 17	1.00		37128.8
16	ZONE 18	1.00		24981.1
17	ZONE 21	1.00		321868.9
18	COMP. ZONE	1.00		6503391.9
19	ZONE 7	.30	ZONE 1	1214.1
20	ZONE 19	1.00		1596770.2

TABLE B5.1 (Cont.)

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
21	ZONE 20	1.00		349314.8

TABLE B5.2

EXPERT 5

LIST OF ALTERNATIVE ZONES OR CLUSTERS OF BOUNDARY ZONES

CLUSTER INDEX	WEIGHT	BACK	OLD / NEW	ZONES IN CLUSTER						
1	.950	COMP. Z		ZONE 3	ZONE 4	ZONE 6	ZONE 5	ZONE 12	ZONE 15	ZONE 14
	.050			ZONE 19	ZONE 20					

TABLE B5.3

SEISMICITY DATA FOR EXPERT 5

NO. OF ZONES= 23   SELF WEIGHTS ARE 10.0 9.0 8.0 7.0   LLNL MODEL   PARTIAL CORRELATION

****

SEQ. # 1   LOC IN REG NO 1   ******** MAP ZONE NAME =ZONE 1
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF   (A-B*I)   MODEL IS   4.00   12.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	10.0	9.0	11.0
A	3.083	2.383	3.783
B	-.680	-.900	-.400

****

SEQ. # 2   LOC IN REG NO 1   ******** MAP ZONE NAME =ZONE 2
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF   (A-B*I)   MODEL IS   4.00   12.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.0	3.0	6.0
A	3.456	2.456	4.456
B	-.500	-.700	-.300

****

SEQ. # 3   LOC IN REG NO 1   ******** MAP ZONE NAME =ZONE 3
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF   (A-B*I)   MODEL IS   4.00   12.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	11.0	10.0	12.0
A	1.751	1.351	2.151
B	-.500	-.700	-.300

****

SEQ. # 4   LOC IN REG NO 1   ******** MAP ZONE NAME =ZONE 4
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF   (A-B*I)   MODEL IS   4.00   12.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	9.0	8.0	10.0
A	2.447	1.947	2.947
B	-.610	-.700	-.400

****

SEQ. # 5   LOC IN REG NO 3   ******** MAP ZONE NAME =ZONE 5
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF   (A-B*I)   MODEL IS   4.00   12.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	9.0	7.0	10.0
A	2.528	2.028	3.028
B	-.740	-.900	-.400

*********** SEISMICITY DATA FOR EXPERT 5 **********

TABLE B5.3 (Cont.)

```
****************************************************************************************************
SEQ. #  6     LOC IN REG NO  3               ******** MAP ZONE NAME =ZONE  6
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS        4.00      12.00

PARAMETER                       BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                            9.0                        7.0                        10.0
    A                                2.728                      1.728                       3.528
    B                                -.500                      -.900                       -.300
****************************************************************************************************
SEQ. #  7     LOC IN REG NO  1               ******** MAP ZONE NAME =ZONE  7
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS        4.00      12.00

PARAMETER                       BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                            8.0                        7.0                         9.0
    A                                1.678                      1.178                       2.178
    B                                -.500                      -.700                       -.300
****************************************************************************************************
SEQ. #  8     LOC IN REG NO  2               ******** MAP ZONE NAME =ZONE  8
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS        4.00      12.00

PARAMETER                       BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                            8.0                        7.0                         9.0
    A                                2.268                      1.868                       2.668
    B                                -.660                      -.800                       -.400
****************************************************************************************************
SEQ. #  9     LOC IN REG NO  2               ******** MAP ZONE NAME =ZONE  9
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS        4.00      12.00

PARAMETER                       BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                           11.0                       10.0                        12.0
    A                                2.736                      2.036                       3.236
    B                                -.540                      -.800                       -.300
****************************************************************************************************
SEQ. # 10     LOC IN REG NO  2               ******** MAP ZONE NAME =ZONE 10
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS        4.00      12.00

PARAMETER                       BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                            8.0                        7.0                         9.0
    A                                2.524                      1.724                       3.324
    B                                -.640                      -.800                       -.400
                       ***********  SEISMICITY DATA FOR EXPERT 5      **********
```

TABLE B5.3 (Cont.)

```
****************************************************************************************************
SEQ. # 11     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 11
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS       4.00      12.00

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          9.0                         8.0                            10.0
    A                              4.093                       2.693                          4.493
    B                              -.820                       -.900                          -.400
****************************************************************************************************
SEQ. # 12     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 12
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS       4.00      12.00

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          9.0                         8.0                            10.0
    A                              2.591                       1.991                          2.991
    B                              -.600                       -.700                          -.400
****************************************************************************************************
SEQ. # 13     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 13
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS       4.00      12.00

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          9.0                         8.0                            10.0
    A                              1.101                       .801                           1.901
    B                              -.480                       -.700                          -.300
****************************************************************************************************
SEQ. # 14     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 14
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS       4.00      12.00

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          9.0                         8.0                            10.0
    A                              2.938                       2.238                          3.538
    B                              -.640                       -.800                          -.400
****************************************************************************************************
SEQ. # 15     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 15
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF        (A-B*I)   MODEL IS       4.00      12.00

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          12.0                        12.0                           12.0
    A                              2.977                       2.377                          3.577
    B                              -.560                       -.800                          -.400
                    ***********  SEISMICITY DATA FOR EXPERT 5       **********
```

TABLE B5.3 (Cont.)

```
************************************************************************************************************
SEQ. # 16     LOC IN REG NO  1                   ******** MAP ZONE NAME =ZONE 16
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF         (A-B*I)   MODEL IS      4.00      12.00

PARAMETER                      BEST ESTIMATE                    LOWER LIMIT                     UPPER LIMIT
UP MAG CO                           8.0                             7.0                              9.0
    A                             1.721                           1.221                            2.221
    B                             -.500                           -.700                            -.300
************************************************************************************************************
SEQ. # 17     LOC IN REG NO  4                   ******** MAP ZONE NAME =ZONE 17
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF         (A-B*I)   MODEL IS      4.00      12.00

PARAMETER                      BEST ESTIMATE                    LOWER LIMIT                     UPPER LIMIT
UP MAG CO                           9.0                             8.0                             10.0
    A                             2.215                           1.215                            3.215
    B                             -.500                           -.700                            -.300
************************************************************************************************************
SEQ. # 18     LOC IN REG NO  4                   ******** MAP ZONE NAME =ZONE 18
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF         (A-B*I)   MODEL IS      4.00      12.00

PARAMETER                      BEST ESTIMATE                    LOWER LIMIT                     UPPER LIMIT
UP MAG CO                           9.0                             8.0                             10.0
    A                             1.367                            .867                            2.367
    B                             -.500                           -.700                            -.300
************************************************************************************************************
SEQ. # 19     LOC IN REG NO  2                   ******** MAP ZONE NAME =ZONE 21
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF         (A-B*I)   MODEL IS      4.00      12.00

PARAMETER                      BEST ESTIMATE                    LOWER LIMIT                     UPPER LIMIT
UP MAG CO                           7.0                             5.0                              8.0
    A                             3.118                           2.018                            4.018
    B                             -.920                          -1.000                            -.400
************************************************************************************************************
SEQ. # 20     LOC IN REG NO  4                   ******** MAP ZONE NAME =  C.Z.
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF         (A-B*I)   MODEL IS      4.00      12.00

PARAMETER                      BEST ESTIMATE                    LOWER LIMIT                     UPPER LIMIT
UP MAG CO                           8.0                             7.0                              9.0
    A                             4.170                           3.370                            4.970
    B                             -.920                          -1.000                            -.400
                         ***********  SEISMICITY DATA FOR EXPERT 5      **********
```

TABLE B5.3 (Cont.)

```
**********************************************************************************************
SEQ. # 21     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 19
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF         (A-B*I)   MODEL IS      4.00     12.00
PARAMETER                     BEST ESTIMATE                LOWER LIMIT                UPPER LIMIT
UP MAG CO                        12.0                         12.0                       12.0
    A                            2.103                        1.803                      2.303
    B                            -.400                        -.600                      -.300
**********************************************************************************************
SEQ. # 22     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE 20
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF         (A-B*I)   MODEL IS      4.00     12.00
PARAMETER                     BEST ESTIMATE                LOWER LIMIT                UPPER LIMIT
UP MAG CO                         9.0                          7.0                       10.0
    A                            2.251                        1.951                      2.551
    B                            -.540                        -.600                      -.300
**********************************************************************************************
SEQ. # 23     LOC IN REG NO  2                  ******** MAP ZONE NAME =ALT C.Z.
OCCURRENCE MODEL IN INTENSITY   LINEAR RANGE OF         (A-B*I)   MODEL IS      4.00     12.00
PARAMETER                     BEST ESTIMATE                LOWER LIMIT                UPPER LIMIT
UP MAG CO                        11.0                         10.0                       12.0
    A                            2.783                        2.583                      3.183
    B                            -.550                        -.600                      -.300
**********************************************************************************************
                 ********* END OF SEISMICITY DATA FOR EXPERT 5     ZONES *****

    EXPERT'S RELATION BETWEEN I(MAX) & MB IS
    I(MAX)=  2.00*MB -3.50
```

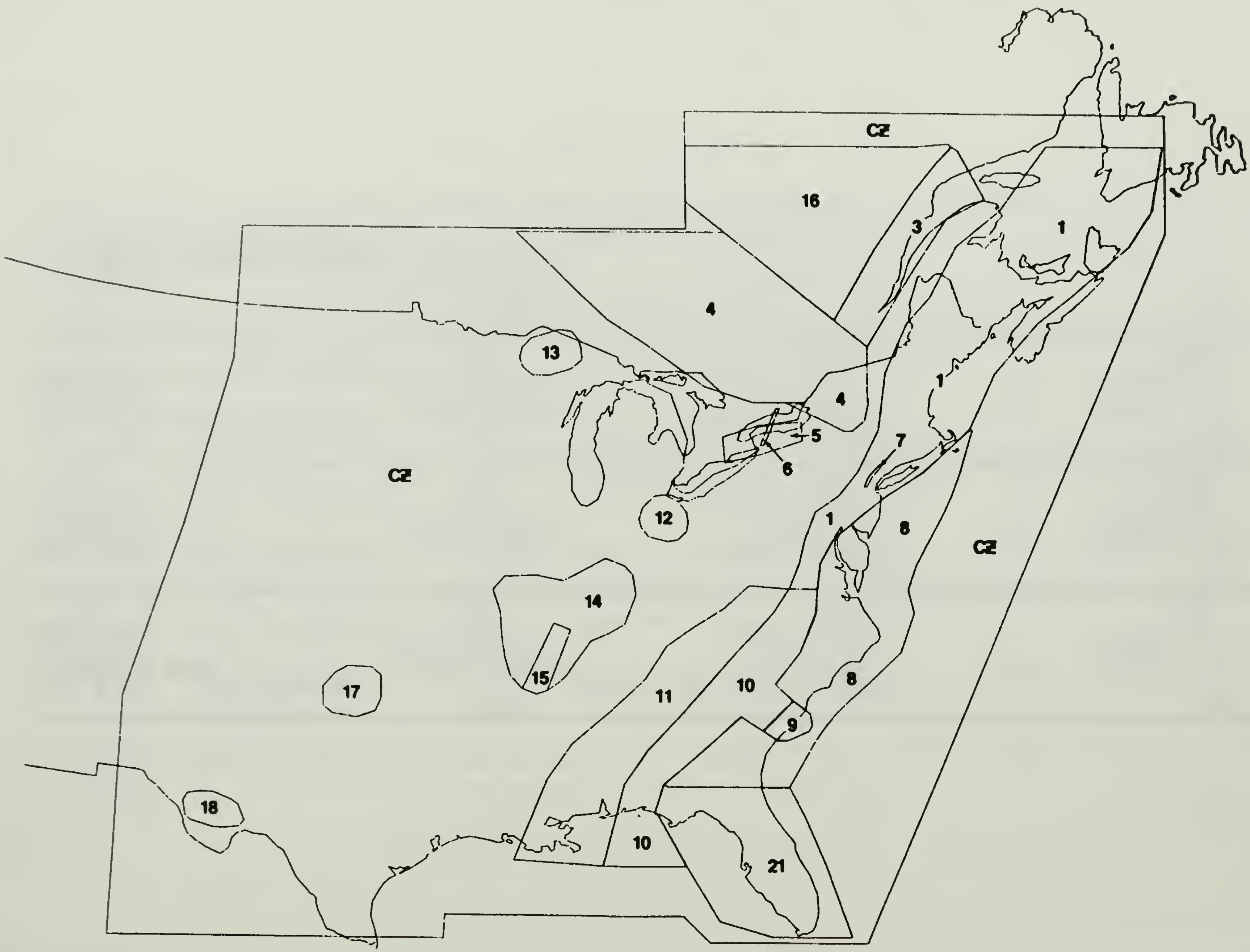

Figure B5.1 Seismic zonation base map for Expert 5

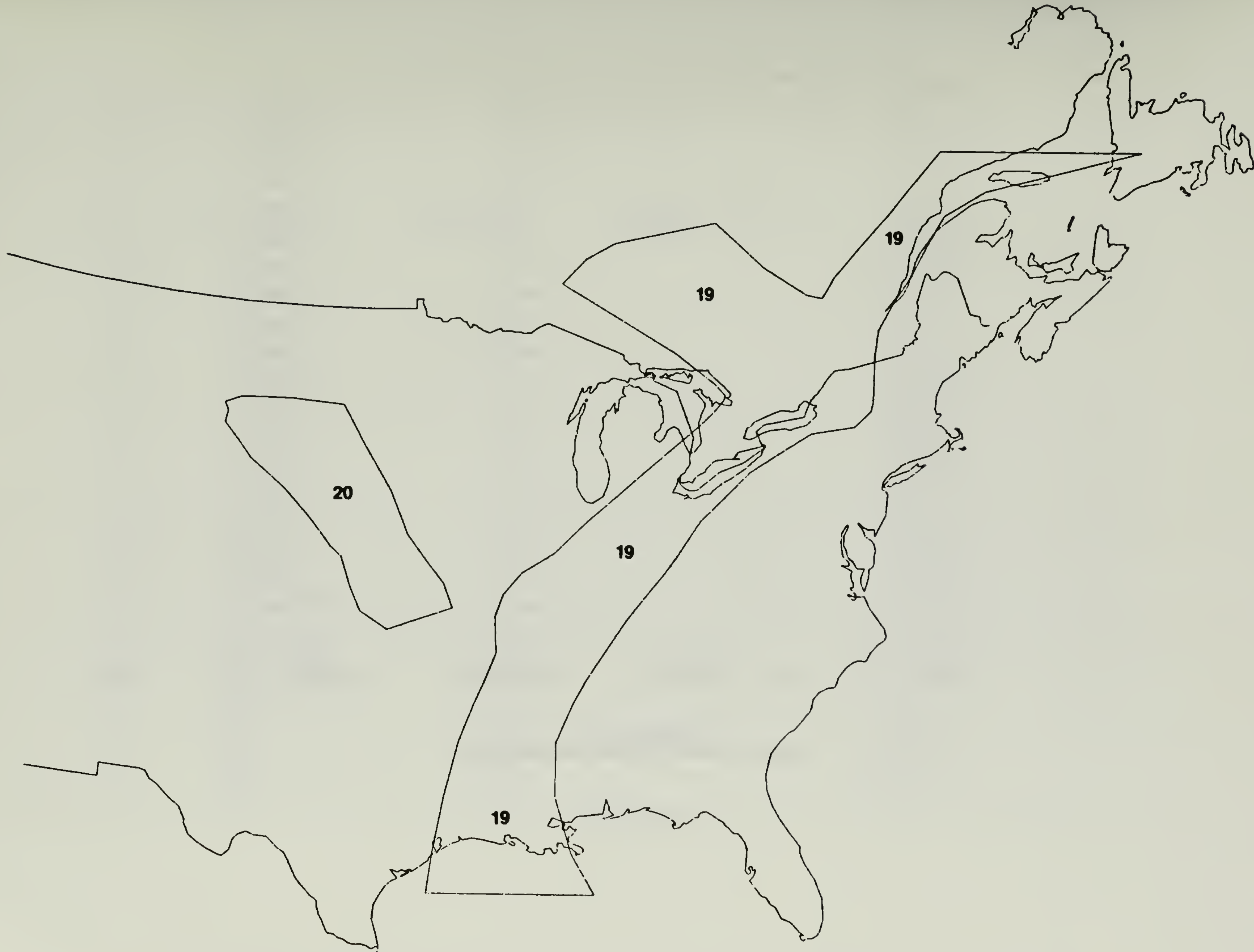

Figure B5.2 Map of alternative seismic zonations to Expert 5's base map.

TABLE B6.1

INFORMATION ABOUT ZONES DEFINED
BY EXPERT 6

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 3	1.00		7535.5
2	ZONE 2	1.00		140009.5
3	ZONE 4	1.00		154978.4
4	ZONE 5	1.00		120909.5
5	ZONE 6	1.00		144907.9
6	ZONE 7	1.00		326870.4
7	ZONE 8	1.00		44559.9
8	ZONE 9	1.00		107635.1
9	ZONE 10	1.00		105183.7
10	ZONE 11	1.00		126343.6
11	ZONE 12	1.00		95512.0
12	ZONE 13	1.00		95266.7
13	ZONE 14	1.00		26218.7
14	ZONE 15	1.00		94722.2
15	ZONE 16	1.00		30033.2
16	ZONE 18	1.00		15450.7
17	ZONE 17	1.00		187865.1
18	ZONE 19	1.00		81686.0
19	ZONE 20	1.00		166980.0
20	ZONE 21	1.00		103284.6

TABLE B6.1 (Cont.)

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
21	ZONE 22	1.00		157049.0
22	ZONE 23	1.00		203845.8
23	ZONE 24	1.00		38741.3
24	ZONE 25	1.00		188672.5
25	ZONE 26	1.00		197296.9
26	ZONE 27	1.00		151917.6
27	ZONE 28	1.00		89882.7
28	ZONE 29	1.00		52096.5
29	ZONE 30	1.00		127754.2
30	ZONE 31	1.00		236747.5
31	ZONE 32	1.00		81771.9
32	ZONE 33	1.00		83897.0
33	COMP. ZONE	1.00		6644233.1
34	COMP. ZONE 1	1.00		0429858.6
35	COMP. ZONE 1	1.00		0429858.6
36	COMP. ZONE 1	1.00		0429858.6
37	ZONE 2	1.00		177674.1
38	ZONE 3	1.00		126300.2
39	ZONE 4	1.00		209777.0
40	ZONE 5	1.00		290084.9

TABLE B6.1 (Cont.)

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
41	ZONE 6	1.00		60618.2
42	ZONE 7	1.00		52148.4
43	ZONE 8	1.00		67064.3
44	ZONE 9	1.00		147252.2
45	ZONE 10	1.00		108907.4
46	ZONE 11	1.00		18915.8
47	ZONE 12	1.00		26162.1
48	ZONE 13	1.00		28079.2
49	ZONE 14	1.00		41253.1
50	ZONE 15	1.00		30499.8
51	ZONE 16	1.00		62393.5
52	ZONE 17	1.00		218663.7
53	ZONE 18	1.00		23756.3
54	ZONE 19	1.00		37539.1
55	ZONE 20	1.00		91134.4
56	ZONE 21	1.00		36549.3
57	ZONE 22	1.00		74183.8
58	ZONE 23	1.00		109274.4
59	ZONE 24	1.00		38931.9
60	ZONE 25	1.00		36673.6

TABLE B6.2

EXPERT 6

LIST OF ALTERNATIVE ZONES OR CLUSTERS OF BOUNDARY ZONES

Expert 6 used three complete maps to represent his uncertainty in the seismic zonation.

Map 1 shown on Fig. B6.1 is his best estimate map.
Map 2 and Map 3 shown on Fig. B6.2 and B6.3 are alternative maps.

Different weights were assigned by Expert 6 to each one of these maps, as follows:

Map 1: weight = 0.6
Map 2: weight = 0.3 (This is the previous BEM used in Bernreuter et. al. 1985).
Map 3: weight = 0.1 (This is a blanket zone including all of the EUS)

* Note For the purpose of the software used in this analysis a set of additional dummy zones was created to allow replacements by Map 2 and Map 3 (i.e. complementary zone 1 with index 35 and 36 in Table B6.1)

TABLE B6.3

SEISMICITY DATA FOR EXPERT 6

```
NO. OF ZONES= 66      SELF WEIGHTS ARE  9.0  7.0  5.0  5.0   LLNL MODEL            FULL    CORRELATION
***************************************************************************************************
SEQ. #  1     LOC IN REG NO  4              ******** MAP ZONE NAME =ZONE  1R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75      6.25
PARAMETER                       BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                           6.0                            5.5                          6.5
    A                               4.070                          3.050                        4.470
    B                              -1.090                         -1.090                        -.950
***************************************************************************************************
SEQ. #  2     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE  2R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75      5.00
PARAMETER                       BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                           7.3                            7.0                          7.5
    A                               4.550                          3.250                        4.800
    B                              -1.400                         -1.400                       -1.150
***************************************************************************************************
SEQ. #  3     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE  3R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75      6.50
PARAMETER                       BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                           7.3                            6.8                          7.5
    A                               2.630                          1.990                        2.970
    B                               -.770                          -.780                        -.710
***************************************************************************************************
SEQ. #  4     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE  4R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75      5.75
PARAMETER                       BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                           7.0                            6.5                          7.5
    A                               3.490                          1.630                        4.000
    B                              -1.090                         -1.100                        -.730
***************************************************************************************************
SEQ. #  5     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE  5R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75      5.75
PARAMETER                       BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                           7.0                            6.5                          7.5
    A                               3.690                          3.340                        4.400
    B                              -1.090                         -1.090                       -1.090
                        ***********  SEISMICITY DATA FOR EXPERT 6      **********
```

TABLE B6.3 (Cont.)

```
*******************************************************************************************
SEQ. #  6     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE  6R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       5.25
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          7.0                          6.5                          7.5
    A                            3.510                        3.050                        3.670
    B                           -1.020                       -1.020                       -1.000
*******************************************************************************************
SEQ. #  7     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE  7R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       6.00
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          7.0                          6.5                          7.5
    A                            3.850                        2.680                        4.200
    B                           -1.000                       -1.050                        -.830
*******************************************************************************************
SEQ. #  8     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE  8R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       5.00
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.0                          7.0
    A                            2.550                        1.700                        2.690
    B                            -.930                        -.930                        -.830
*******************************************************************************************
SEQ. #  9     LOC IN REG NO  3              ******** MAP ZONE NAME =ZONE  9R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       5.25
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.8                          6.3                          7.3
    A                            2.630                        1.830                        3.550
    B                            -.860                       -1.000                        -.780
*******************************************************************************************
SEQ. # 10     LOC IN REG NO  3              ******** MAP ZONE NAME =ZONE 10R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       4.75
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.0                          7.0
    A                            2.950                        2.450                        3.170
    B                           -1.040                       -1.040                       -1.040
                    ***********  SEISMICITY DATA FOR EXPERT 6        **********
```

TABLE B6.3 (Cont.)

```
**********************************************************************************************
SEQ. # 11     LOC IN REG NO  2                       ******** MAP ZONE NAME =ZONE 11R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75      5.75
PARAMETER                      BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          7.0                          6.5                          7.5
    A                              3.730                        3.050                        3.980
    B                             -1.080                       -1.080                       -1.000
**********************************************************************************************
SEQ. # 12     LOC IN REG NO  2                       ******** MAP ZONE NAME =ZONE 12R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75      5.25
PARAMETER                      BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.0                          7.0
    A                              3.750                        2.550                        4.560
    B                             -1.180                       -1.300                       -1.000
**********************************************************************************************
SEQ. # 13     LOC IN REG NO  2                       ******** MAP ZONE NAME =ZONE 13R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75      6.75
PARAMETER                      BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          7.3                          6.8                          7.5
    A                              2.770                        1.680                        3.080
    B                              -.850                        -.850                        -.750
**********************************************************************************************
SEQ. # 14     LOC IN REG NO  2                       ******** MAP ZONE NAME =ZONE 14R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75      4.75
PARAMETER                      BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.0                          7.0
    A                              2.400                        1.700                        3.120
    B                             -1.000                       -1.300                        -.900
**********************************************************************************************
SEQ. # 15     LOC IN REG NO  2                       ******** MAP ZONE NAME =ZONE 15R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75      5.00
PARAMETER                      BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.0                          7.0
    A                              3.530                        3.280                        3.780
    B                             -1.080                       -1.080                       -1.080
                        ***********  SEISMICITY DATA FOR EXPERT 6      **********
```

TABLE B6.3 (Cont.)

```
*****************************************************************************************
SEQ. # 16     LOC IN REG NO  2                    ******** MAP ZONE NAME =ZONE 16R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       4.75

PARAMETER                        BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                            6.5                          6.0                          7.0
    A                              2.510                        1.250                        2.680
    B                             -1.130                       -1.130                        -.900
*****************************************************************************************
SEQ. # 17     LOC IN REG NO  3                    ******** MAP ZONE NAME =ZONE 17R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       5.75

PARAMETER                        BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                            7.3                          6.8                          7.5
    A                              3.640                        3.390                        3.890
    B                              -.930                        -.930                        -.930
*****************************************************************************************
SEQ. # 18     LOC IN REG NO  3                    ******** MAP ZONE NAME =ZONE 18R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       7.00

PARAMETER                        BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                            7.3                          6.8                          7.5
    A                              2.650                        1.650                        3.830
    B                              -.900                       -1.030                        -.700
*****************************************************************************************
SEQ. # 19     LOC IN REG NO  4                    ******** MAP ZONE NAME =ZONE 19R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       4.75

PARAMETER                        BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                            6.8                          6.3                          7.3
    A                              2.900                        2.200                        3.200
    B                             -1.000                       -1.000                       -1.000
*****************************************************************************************
SEQ. # 20     LOC IN REG NO  4                    ******** MAP ZONE NAME =ZONE 20R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       4.75

PARAMETER                        BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                            6.5                          6.0                          7.0
    A                              2.450                        1.950                        3.220
    B                             -1.000                       -1.100                       -1.000
                          ***********  SEISMICITY DATA FOR EXPERT 6      **********
```

TABLE B6.3 (Cont.)

```
**********************************************************************************************
SEQ. # 21     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE 21R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS         3.75      4.75
PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                              6.5                          6.0                            7.0
    A                                2.570                        2.170                          2.970
    B                               -1.040                       -1.040                         -1.040
**********************************************************************************************
SEQ. # 22     LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 22R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS         3.75      4.75
PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                              6.5                          6.0                            7.0
    A                                2.950                        2.180                          3.150
    B                               -1.020                       -1.020                          -.900
**********************************************************************************************
SEQ. # 23     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE 23R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS         3.75      5.00
PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                              7.0                          6.5                            7.5
    A                                2.850                        1.550                          3.990
    B                               -1.000                       -1.180                          -.800
**********************************************************************************************
SEQ. # 24     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE 24R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS         3.75      4.75
PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                              6.5                          6.0                            7.0
    A                                3.940                        2.600                          4.440
    B                               -1.400                       -1.400                         -1.150
**********************************************************************************************
SEQ. # 25     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE 25R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS         3.75      5.50
PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                              6.8                          6.3                            7.3
    A                                3.070                        2.100                          3.570
    B                                -.950                         -.950                          -.850
                          ***********  SEISMICITY DATA FOR EXPERT 6        **********
```

TABLE B6.3 (Cont.)

SEQ. # 26 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 26R
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	6.0	7.0
A	3.580	3.080	4.080
B	-1.070	-1.070	-1.070

SEQ. # 27 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 27R
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 4.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	6.0	7.0
A	2.550	2.050	3.550
B	-1.000	-1.000	-1.000

SEQ. # 28 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 28R
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 4.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	6.0	7.0
A	3.680	2.550	4.180
B	-1.000	-1.080	-.920

SEQ. # 29 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 29R
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 4.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	6.0	7.0
A	4.040	1.800	4.540
B	-1.270	-1.270	-1.000

SEQ. # 30 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 30R
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 4.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	6.0	7.0
A	3.180	2.600	3.850
B	-1.010	-1.010	-1.010

*********** SEISMICITY DATA FOR EXPERT 6 **********

TABLE B6.3 (Cont.)

```
****************************************************************************************************
SEQ. # 31      LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 31R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF        (A-B*M)    MODEL IS          3.75       4.75
PARAMETER                  BEST ESTIMATE                     LOWER LIMIT                      UPPER LIMIT
UP MAG CO                       6.5                              6.0                              7.0
    A                           3.700                            2.550                            4.350
    B                          -1.130                           -1.130                           -1.000
****************************************************************************************************
SEQ. # 32      LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 32R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF        (A-B*M)    MODEL IS          3.75       5.50
PARAMETER                  BEST ESTIMATE                     LOWER LIMIT                      UPPER LIMIT
UP MAG CO                       6.5                              6.0                              7.0
    A                           2.680                            2.080                            3.080
    B                          -1.030                           -1.030                           -1.030
****************************************************************************************************
SEQ. # 33      LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 33R
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF        (A-B*M)    MODEL IS          3.75       4.75
PARAMETER                  BEST ESTIMATE                     LOWER LIMIT                      UPPER LIMIT
UP MAG CO                       6.5                              6.0                              7.0
    A                           2.700                            1.400                            3.200
    B                          -1.000                           -1.000                            -.750
****************************************************************************************************
SEQ. # 34      LOC IN REG NO  3                  ******** MAP ZONE NAME =DUMMY C. Z.
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF        (A-B*M)    MODEL IS          3.75       4.25
PARAMETER                  BEST ESTIMATE                     LOWER LIMIT                      UPPER LIMIT
UP MAG CO                       5.3                              5.0                              5.5
    A                           0.000                            0.000                            0.000
    B                          -1.000                           -1.000                           -1.000
****************************************************************************************************
SEQ. # 35      LOC IN REG NO  3                  ******** MAP ZONE NAME =DUMMY C. Z.
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF        (A-B*M)    MODEL IS          3.75       4.25
PARAMETER                  BEST ESTIMATE                     LOWER LIMIT                      UPPER LIMIT
UP MAG CO                       5.3                              5.0                              5.5
    A                           0.000                            0.000                            0.000
    B                          -1.000                           -1.000                           -1.000
                      ***********  SEISMICITY DATA FOR EXPERT 6        **********
```

TABLE B6.3 (Cont.)

****

SEQ. # 36 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 34 SINGLE ZO
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 7.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.3	6.8	7.5
A	4.550	3.830	4.850
B	-1.000	-1.000	-.920

****

SEQ. # 37 LOC IN REG NO 3 ******** MAP ZONE NAME =MAP2 ZONE 1
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 6.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.5	6.5
A	4.250	3.750	4.750
B	-1.100	-1.100	-1.100

****

SEQ. # 38 LOC IN REG NO 1 ******** MAP ZONE NAME =MAP2 ZONE 2
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.0	6.5	7.5
A	3.550	2.550	4.050
B	-1.100	-1.100	-1.000

****

SEQ. # 39 LOC IN REG NO 1 ******** MAP ZONE NAME =MAP2 ZONE 3
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 6.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.3	6.8	7.5
A	3.050	2.300	3.150
B	-.850	-1.000	-.850

****

SEQ. # 40 LOC IN REG NO 1 ******** MAP ZONE NAME =MAP2 ZONE 4
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.0	6.5	7.5
A	3.900	3.400	4.400
B	-1.050	-1.050	-1.050

*********** SEISMICITY DATA FOR EXPERT 6 **********

TABLE B6.3 (Cont.)

```
****************************************************************************************************
SEQ. # 41     LOC IN REG NO  1                    ******** MAP ZONE NAME =MAP2 ZONE 5
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       6.00
PARAMETER                       BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                            7.0                          6.5                          7.5
     A                               3.950                        3.450                        4.450
     B                              -1.000                       -1.000                       -1.000
****************************************************************************************************
SEQ. # 42     LOC IN REG NO  3                    ******** MAP ZONE NAME =MAP2 ZONE 6
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       5.00
PARAMETER                       BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                            6.5                          6.0                          7.0
     A                               2.550                        2.050                        3.050
     B                               -.900                       -1.000                        -.900
****************************************************************************************************
SEQ. # 43     LOC IN REG NO  2                    ******** MAP ZONE NAME =MAP2 ZONE 7
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       5.25
PARAMETER                       BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                            6.5                          6.0                          7.0
     A                               2.550                        2.050                        3.050
     B                              -1.000                       -1.000                       -1.000
****************************************************************************************************
SEQ. # 44     LOC IN REG NO  2                    ******** MAP ZONE NAME =MAP2 ZONE 8
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       5.00
PARAMETER                       BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                            6.5                          6.0                          7.0
     A                               3.150                        2.650                        3.650
     B                              -1.000                       -1.000                       -1.000
****************************************************************************************************
SEQ. # 45     LOC IN REG NO  2                    ******** MAP ZONE NAME =MAP2 ZONE 9
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       5.75
PARAMETER                       BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                            7.0                          6.5                          7.5
     A                               4.050                        3.050                        4.550
     B                              -1.100                       -1.100                       -1.000
                         ***********  SEISMICITY DATA FOR EXPERT 6       **********
```

TABLE B6.3 (Cont.)

```
************************************************************************************************
SEQ. # 46     LOC IN REG NO  2               ******** MAP ZONE NAME =MAP2 ZONE 10
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      6.75

PARAMETER                     BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         7.3                            6.8                          7.5
    A                             3.000                          2.450                        4.250
    B                             -.900                         -1.000                        -.900
************************************************************************************************
SEQ. # 47     LOC IN REG NO  2               ******** MAP ZONE NAME =MAP2 ZONE 11
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      4.75

PARAMETER                     BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.5                            6.0                          7.0
    A                             2.650                          2.150                        3.150
    B                            -1.050                         -1.050                       -1.050
************************************************************************************************
SEQ. # 48     LOC IN REG NO  2               ******** MAP ZONE NAME =MAP2 ZONE 12
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      4.75

PARAMETER                     BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.5                            6.0                          7.0
    A                             1.950                          1.450                        2.650
    B                            -1.000                         -1.050                       -1.000
************************************************************************************************
SEQ. # 49     LOC IN REG NO  2               ******** MAP ZONE NAME =MAP2 ZONE 13
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      4.75

PARAMETER                     BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.5                            6.0                          7.0
    A                             2.460                          1.350                        2.960
    B                            -1.150                         -1.150                       -1.000
************************************************************************************************
SEQ. # 50     LOC IN REG NO  3               ******** MAP ZONE NAME =MAP2 ZONE 14
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      4.75

PARAMETER                     BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.5                            6.0                          7.0
    A                             2.250                          1.800                        3.400
    B                            -1.000                         -1.150                       -1.000
                        ***********  SEISMICITY DATA FOR EXPERT 6       **********
```

TABLE B6.3 (Cont.)

```
****************************************************************************************************
SEQ. # 51     LOC IN REG NO  3                   ******** MAP ZONE NAME =MAP2 ZONE 15
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      4.75
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                UPPER LIMIT
UP MAG CO                        6.5                            6.0                        7.0
    A                            2.250                          1.750                      3.100
    B                            -.950                          -1.000                     -.950
****************************************************************************************************
SEQ. # 52     LOC IN REG NO  3                   ******** MAP ZONE NAME =MAP2 ZONE 16
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      5.25
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                UPPER LIMIT
UP MAG CO                        6.8                            6.3                        7.3
    A                            2.500                          2.000                      3.850
    B                            -.850                          -1.000                     -.850
****************************************************************************************************
SEQ. # 53     LOC IN REG NO  4                   ******** MAP ZONE NAME =MAP2 ZONE 17
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      7.00
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                UPPER LIMIT
UP MAG CO                        7.3                            6.8                        7.5
    A                            3.530                          3.030                      4.800
    B                            -.900                          -1.000                     -.900
****************************************************************************************************
SEQ. # 54     LOC IN REG NO  4                   ******** MAP ZONE NAME =MAP2 ZONE 18
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      4.75
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                UPPER LIMIT
UP MAG CO                        6.8                            6.3                        7.3
    A                            2.600                          1.950                      3.100
    B                            -1.000                         -1.000                     -1.000
****************************************************************************************************
SEQ. # 55     LOC IN REG NO  4                   ******** MAP ZONE NAME =MAP2 ZONE 19
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      4.75
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                UPPER LIMIT
UP MAG CO                        6.8                            6.3                        7.3
    A                            1.900                          1.400                      3.150
    B                            -.850                          -1.000                     -.850
                     ***********  SEISMICITY DATA FOR EXPERT 6       **********
```

TABLE B6.3 (Cont.)

```
****************************************************************************************************
SEQ. # 56     LOC IN REG NO  4                ******** MAP ZONE NAME =MAP2 ZONE 20
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      4.75

PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.5                          6.0                          7.0
    A                            2.450                        1.950                        2.950
    B                           -1.000                       -1.000                       -1.000
****************************************************************************************************
SEQ. # 57     LOC IN REG NO  4                ******** MAP ZONE NAME =MAP2 ZONE 21
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      4.75

PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.5                          6.0                          7.0
    A                            1.900                        1.400                        2.650
    B                           -1.000                       -1.000                        -.950
****************************************************************************************************
SEQ. # 58     LOC IN REG NO  4                ******** MAP ZONE NAME =MAP2 ZONE 22
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      5.50

PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.8                          6.3                          7.3
    A                            3.100                        2.600                        3.600
    B                           -1.000                       -1.000                       -1.000
****************************************************************************************************
SEQ. # 59     LOC IN REG NO  3                ******** MAP ZONE NAME =MAP2 ZONE 23
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      5.00

PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.5                          6.0                          7.0
    A                            2.550                        1.550                        3.600
    B                           -1.000                       -1.150                        -.900
****************************************************************************************************
SEQ. # 60     LOC IN REG NO  3                ******** MAP ZONE NAME =MAP2 ZONE 24
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      4.75

PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.5                          6.0                          7.0
    A                            1.900                        1.400                        2.400
    B                           -1.000                       -1.000                       -1.000
                        ***********  SEISMICITY DATA FOR EXPERT 6      **********
```

TABLE B6.3 (Cont.)

```
****************************************************************************************************
SEQ. # 61     LOC IN REG NO  3                ******** MAP ZONE NAME =MAP2 ZONE 25
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       5.00

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.0                          7.0
    A                              2.350                        1.850                        2.850
    B                             -1.000                       -1.000                       -1.000
****************************************************************************************************
SEQ. # 62     LOC IN REG NO  3                ******** MAP ZONE NAME =MAP2 ZONE 26
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       4.75

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.0                          7.0
    A                              3.950                        2.400                        4.450
    B                             -1.200                       -1.200                       -1.000
****************************************************************************************************
SEQ. # 63     LOC IN REG NO  3                ******** MAP ZONE NAME =MAP2 ZONE 27
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       4.75

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.0                          7.0
    A                              3.550                        2.350                        4.050
    B                             -1.150                       -1.150                       -1.000
****************************************************************************************************
SEQ. # 64     LOC IN REG NO  3                ******** MAP ZONE NAME =MAP2 ZONE 28
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       4.75

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.0                          7.0
    A                              2.750                        2.250                        3.550
    B                              -.950                       -1.000                        -.950
****************************************************************************************************
SEQ. # 65     LOC IN REG NO  4                ******** MAP ZONE NAME =MAP2 ZONE 29
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       5.00

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.0                          7.0
    A                              3.150                        2.450                        3.650
    B                             -1.050                       -1.050                       -1.000
                        ***********  SEISMICITY DATA FOR EXPERT 6       **********
```

TABLE B6.3 (Cont.)

```
****************************************************************************************************
SEQ. # 66     LOC IN REG NO  4             ******** MAP ZONE NAME =MAP2 ZONE 30
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       5.75

PARAMETER                     BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          7.0                        6.5                         7.5
    A                              1.750                      1.250                       3.150
    B                              -.800                     -1.000                       -.800
****************************************************************************************************

                   ********* END OF SEISMICITY DATA FOR EXPERT 6     ZONES *****


     EXPERT'S RELATION BETWEEN I(MAX) & MB IS
     I(MAX)=  2.00*MB -3.50
```

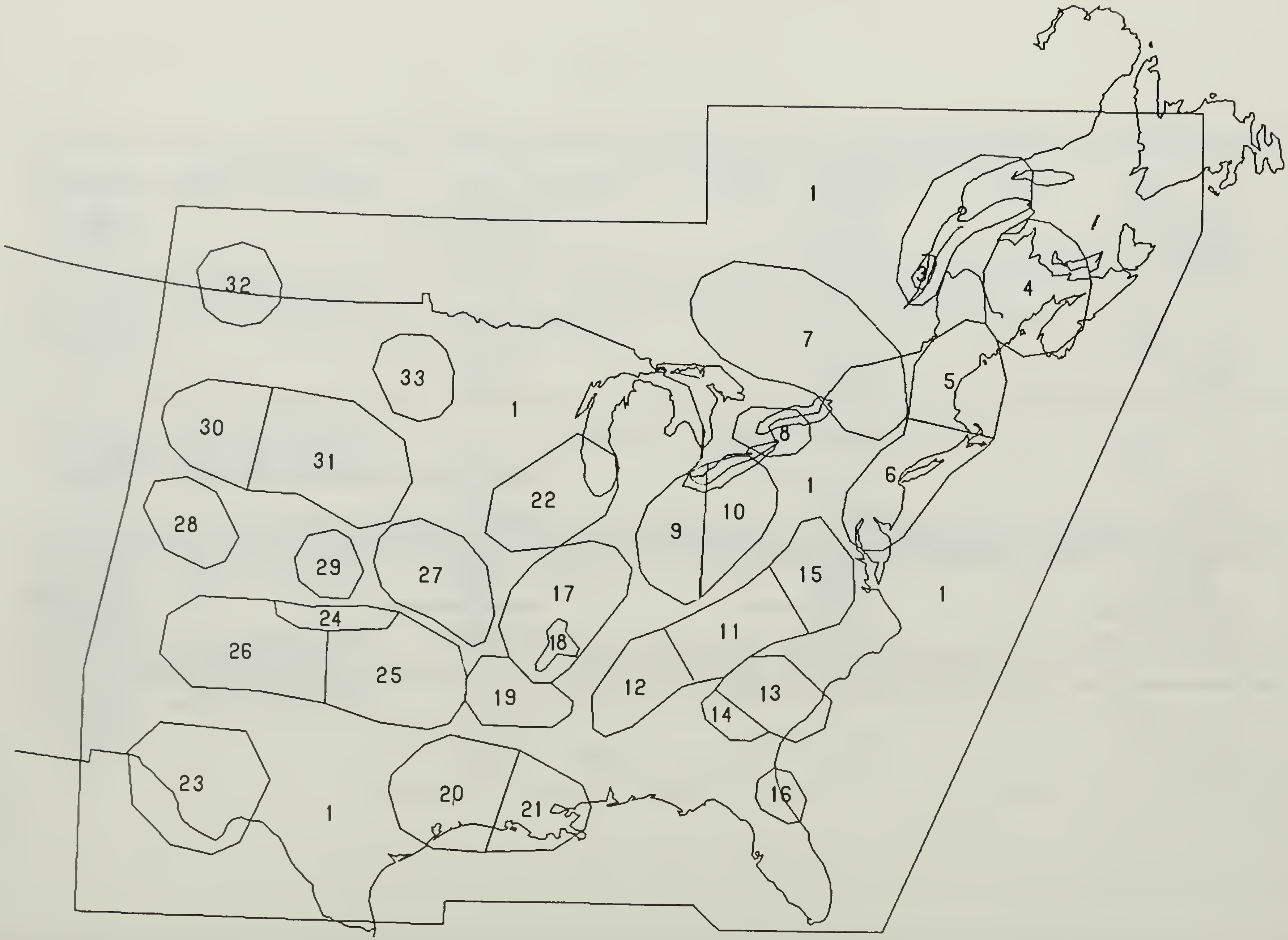

Figure B6.1 Seismic zonation base map for Expert 6

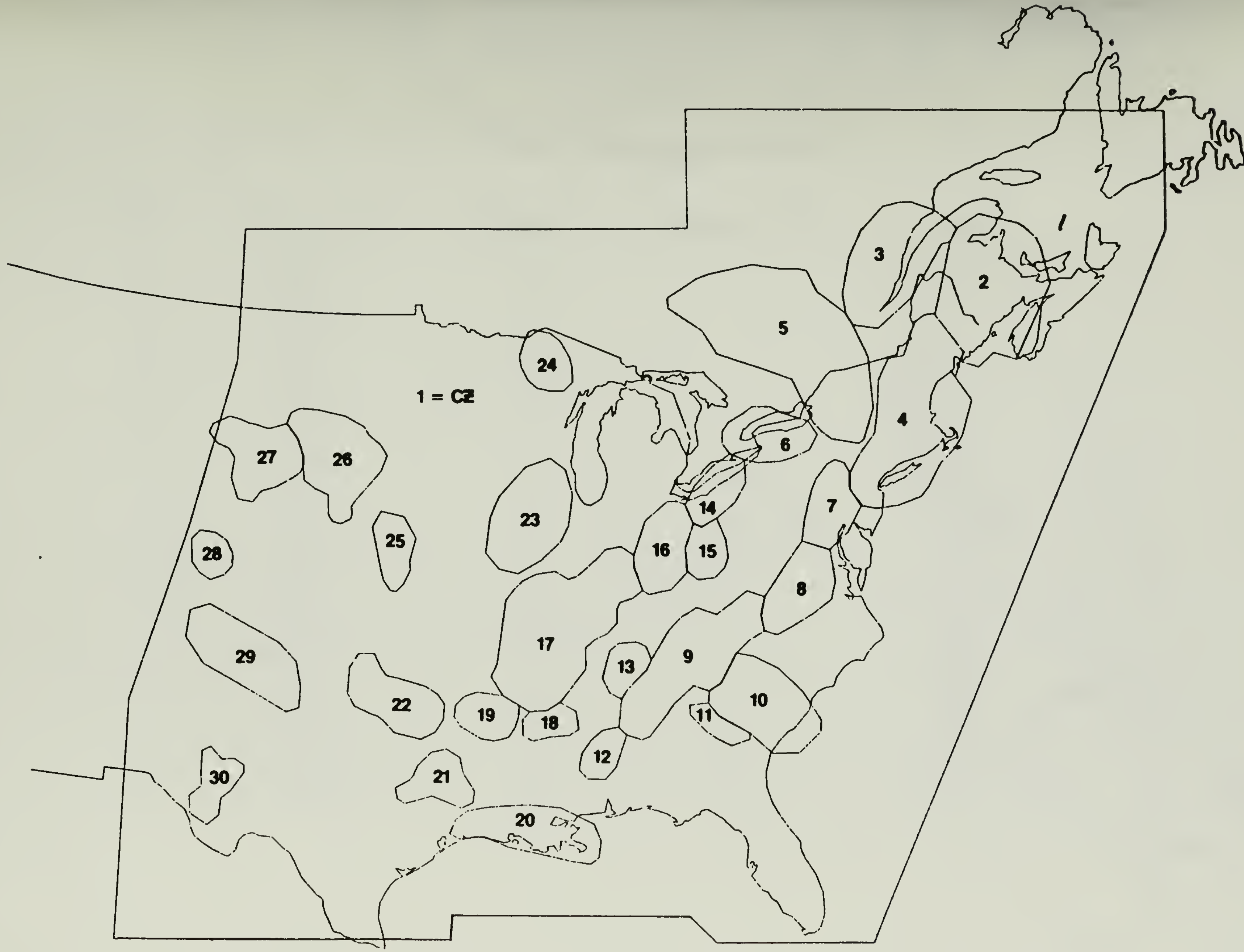

Figure B6.2 Seismic zonation map alternative 1 to Expert 6's base map.

Figure B6.3 Seismic zonation map alternative 2 to Expert 6's base map.

TABLE B7.1

INFORMATION ABOUT ZONES DEFINED
BY EXPERT 7

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 1	1.00		1102900.8
2	ZONE 4	1.00		282322.1
3	ZONE 18	1.00		2116.0
4	ZONE 17	1.00		205711.5
5	ZONE 3	1.00		1311668.3
6	ZONE 6	1.00		5711.1
7	ZONE 5	1.00		197742.7
8	ZONE 7	1.00		311868.8
9	ZONE 8	1.00		123913.9
10	ZONE 9	1.00		41689.0
11	ZONE 10	1.00		6893.5
12	ZONE 11	1.00		14390.5
13	ZONE 12	1.00		4723.0
14	ZONE 13	1.00		5340.5
15	ZONE 14	1.00		6662.1
16	ZONE 15	1.00		4629.1
17	ZONE 16	1.00		9747.3
18	ZONE 19	1.00		33381.0
19	ZONE 23	1.00		9799.3
20	ZONE 25	1.00		440203.7

TABLE B7.1 (Cont.)

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
21	ZONE 26	1.00		19576.0
22	ZONE 27	1.00		33222.2
23	ZONE 28	1.00		11158.5
24	ZONE 29	1.00		56895.3
25	ZONE 30	1.00		351490.6
26	ZONE 31	1.00		95706.0
27	ZONE 32	1.00		38930.7
28	ZONE 33	1.00		337464.0
29	ZONE 34	1.00		39188.7
30	ZONE 35	1.00		282414.1
31	ZONE 36	1.00		7841.0
32	ZONE 24	1.00		347874.0
33	ZONE 41	1.00		226152.2
34	ZONE 2 = CZ	1.00		4468358.2

TABLE B7.3

```
                              SEISMICITY DATA FOR EXPERT 7

NO. OF ZONES= 34     SELF WEIGHTS ARE  9.0  7.0  6.0  7.0   LLNL MODEL           NO       CORRELATION
****************************************************************************************************
SEQ. #  1      LOC IN REG NO  4                 ******** MAP ZONE NAME =ZONE  1
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.50       4.75
PARAMETER                       BEST ESTIMATE                   LOWER LIMIT                    UPPER LIMIT
UP MAG CO                            5.8                            4.8                            6.3
     A                               3.500                          3.100                          3.900
     B                              -1.100                         -1.400                          -.800
****************************************************************************************************
SEQ. #  2      LOC IN REG NO  4                 ******** MAP ZONE NAME =ZONE 2 = CZ
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.50       5.75
PARAMETER                       BEST ESTIMATE                   LOWER LIMIT                    UPPER LIMIT
UP MAG CO                            5.8                            5.0                            6.0
     A                               4.150                          3.850                          4.480
     B                              -1.100                         -1.400                          -.800
****************************************************************************************************
SEQ. #  3      LOC IN REG NO  3                 ******** MAP ZONE NAME =ZONE  3
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.50       5.50
PARAMETER                       BEST ESTIMATE                   LOWER LIMIT                    UPPER LIMIT
UP MAG CO                            6.3                            5.5                            6.5
     A                               3.500                          3.400                          3.600
     B                              -1.100                         -1.400                          -.800
****************************************************************************************************
SEQ. #  4      LOC IN REG NO  3                 ******** MAP ZONE NAME =ZONE  4
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.50       4.75
PARAMETER                       BEST ESTIMATE                   LOWER LIMIT                    UPPER LIMIT
UP MAG CO                            5.8                            4.8                            6.3
     A                               3.000                          2.800                          3.200
     B                              -1.100                         -1.400                          -.800
****************************************************************************************************
SEQ. #  5      LOC IN REG NO  4                 ******** MAP ZONE NAME =ZONE  5
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.50       6.00
PARAMETER                       BEST ESTIMATE                   LOWER LIMIT                    UPPER LIMIT
UP MAG CO                            6.5                            6.0                            6.8
     A                               4.500                          4.400                          4.600
     B                              -1.100                         -1.400                          -.800
                         ***********  SEISMICITY DATA FOR EXPERT 7       **********
```

TABLE B7.3 (Cont.)

****

SEQ. # 6 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 6
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 7.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.8	7.3	8.0
A	5.340	4.710	5.970
B	-1.100	-1.400	-.800

****

SEQ. # 7 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 7
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	5.8	6.8
A	4.300	4.020	4.580
B	-1.100	-1.400	-.800

****

SEQ. # 8 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 8
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.3	6.3
A	3.620	3.520	3.720
B	-1.100	-1.400	-.800

****

SEQ. # 9 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 9
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	5.0	6.0
A	3.610	3.250	3.970
B	-1.100	-1.400	-.800

****

SEQ. # 10 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 10
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 6.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.3	6.8	7.5
A	4.450	3.640	5.260
B	-1.100	-1.400	-.800

*********** SEISMICITY DATA FOR EXPERT 7 **********

TABLE B7.3 (Cont.)

****

SEQ. # 11 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 11
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.3	6.3
A	3.550	3.330	3.770
B	-1.100	-1.400	-.800

****

SEQ. # 12 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 12
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	5.0	6.0
A	3.300	2.950	3.650
B	-1.100	-1.400	-.800

****

SEQ. # 13 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 13
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.3	6.3
A	3.320	3.150	3.490
B	-1.100	-1.400	-.800

****

SEQ. # 14 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 14
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.3	6.3
A	3.300	3.080	3.520
B	-1.100	-1.400	-.800

****

SEQ. # 15 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 15
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 4.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.3	4.3	5.8
A	2.960	2.860	3.060
B	-1.100	-1.400	-.800

*********** SEISMICITY DATA FOR EXPERT 7 **********

TABLE B7.3 (Cont.)

```
*******************************************************************************************
SEQ. # 16     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 16
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      4.50

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                 UPPER LIMIT
UP MAG CO                         4.8                          4.3                          5.3
   A                              2.080                        1.980                        2.180
   B                             -1.100                       -1.400                        -.800
*******************************************************************************************
SEQ. # 17     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 17
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      6.00

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                 UPPER LIMIT
UP MAG CO                         6.5                          6.0                          6.8
   A                              4.600                        4.150                        5.050
   B                             -1.100                       -1.400                        -.800
*******************************************************************************************
SEQ. # 18     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 18
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      5.75

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                 UPPER LIMIT
UP MAG CO                         6.5                          5.8                          6.8
   A                              4.150                        3.400                        4.890
   B                             -1.100                       -1.400                        -.800
*******************************************************************************************
SEQ. # 19     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 19
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      5.75

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                 UPPER LIMIT
UP MAG CO                         6.5                          5.8                          6.8
   A                              3.940                        3.840                        4.040
   B                             -1.100                       -1.400                        -.800
*******************************************************************************************
SEQ. # 20     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 23
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.50      5.00

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                 UPPER LIMIT
UP MAG CO                         6.5                          5.7                          6.8
   A                              3.730                        3.030                        4.330
   B                             -1.100                       -1.400                        -.800
                   ***********  SEISMICITY DATA FOR EXPERT 7       **********
```

TABLE B7.3 (Cont.)

****

SEQ. # 21 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 24
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 4.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	4.8	6.3
A	4.000	3.650	4.350
B	-1.100	-1.400	-.800

****

SEQ. # 22 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 25
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 4.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	4.8	6.3
A	3.470	2.520	4.220
B	-1.100	-1.400	-.800

****

SEQ. # 23 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 26
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 6.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.0	6.5	7.3
A	4.530	4.150	4.910
B	-1.100	-1.400	-.800

****

SEQ. # 24 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 27
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	5.0	6.0
A	3.470	2.800	4.140
B	-1.100	-1.400	-.800

****

SEQ. # 25 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 28
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 4.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.3	4.3	5.8
A	3.020	2.750	3.290
B	-1.100	-1.400	-.800

*********** SEISMICITY DATA FOR EXPERT 7 **********

TABLE B7.3 (Cont.)

```
****************************************************************************************************
SEQ. # 26      LOC IN REG NO  2                    ******** MAP ZONE NAME =ZONE 29
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.50      5.25

PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                              6.0                          5.3                          6.3
    A                                  3.550                        3.280                        3.820
    B                                 -1.100                       -1.400                        -.800
****************************************************************************************************
SEQ. # 27      LOC IN REG NO  4                    ******** MAP ZONE NAME =ZONE 30
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.50      5.50

PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                              6.5                          5.5                          6.8
    A                                  4.150                        3.700                        4.600
    B                                 -1.100                       -1.400                        -.800
****************************************************************************************************
SEQ. # 28      LOC IN REG NO  3                    ******** MAP ZONE NAME =ZONE 31
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.50      5.00

PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                              5.8                          5.0                          6.0
    A                                  3.070                        2.970                        3.170
    B                                 -1.100                       -1.400                        -.800
****************************************************************************************************
SEQ. # 29      LOC IN REG NO  3                    ******** MAP ZONE NAME =ZONE 32
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.50      4.25

PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                              5.3                          4.3                          5.8
    A                                  3.060                        2.550                        3.570
    B                                 -1.100                       -1.400                        -.800
****************************************************************************************************
SEQ. # 30      LOC IN REG NO  3                    ******** MAP ZONE NAME =ZONE 33
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.50      4.75

PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                              5.8                          4.8                          6.3
    A                                  4.120                        3.580                        4.660
    B                                 -1.100                       -1.400                        -.800
                            ***********  SEISMICITY DATA FOR EXPERT 7       **********
```

TABLE B7.3 (Cont.)

SEQ. # 31 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE 34
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	5.0	6.0
A	2.950	2.850	3.050
B	-1.100	-1.400	-.800

SEQ. # 32 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 35
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 6.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.8	6.3	7.0
A	4.150	4.050	4.250
B	-1.100	-1.400	-.800

SEQ. # 33 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 36
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	5.8	6.8
A	3.840	2.630	5.050
B	-1.100	-1.400	-.800

SEQ. # 34 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 41
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.50 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	5.0	6.0
A	3.640	3.220	4.060
B	-1.100	-1.400	-.800

********* END OF SEISMICITY DATA FOR EXPERT 7 ZONES *****

EXPERT'S RELATION BETWEEN I(MAX) & MB IS
I(MAX)= 2.00*MB -3.50

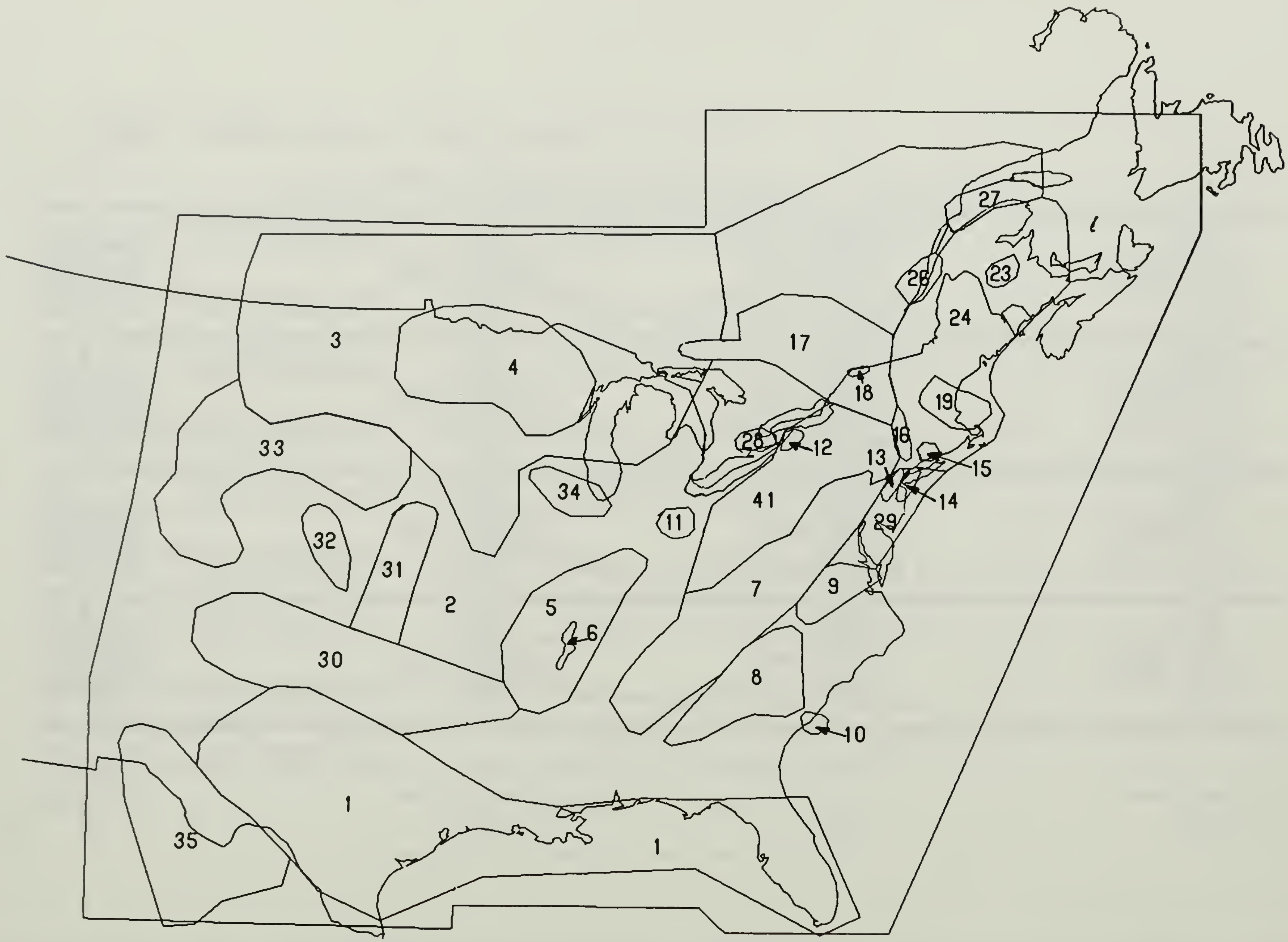

Figure 7.1 Seismic zonation base map for Expert 7.

TABLE B10.1

INFORMATION ABOUT ZONES DEFINED
BY EXPERT 10

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 20	.90	ZONE 1	4561.2
2	ZONE 1	.80	ZONE 19 = CZ	134314.3
3	ZONE 2	.80	ZONE 19 = CZ	36111.9
4	ZONE 3	.80	ZONE 19 = CZ	121138.4
5	ZONE 15	.90	ZONE 4B	6921.8
6	ZONE 4B	.80	ZONE 19 = CZ	427422.9
7	ZONE 5	.70	ZONE 19 = CZ	104872.1
8	ZONE 6	.70	ZONE 19 = CZ	30637.9
9	ZONE 7	.99	ZONE 19 = CZ	129793.7
10	ZONE 8	1.00		2268.8
11	ZONE 9	.70	ZONE 10	5802.9
12	ZONE 10	.80	ZONE 19 = CZ	19360.9
13	ZONE 12A	.95	ZONE 19 = CZ	15527.1
14	ZONE 13	.98	ZONE 19 = CZ	97361.9
15	ZONE 16	.75	ZONE 19 = CZ	33227.3
16	ZONE 17	.70	ZONE 18	18110.6
17	ZONE 18	.95	ZONE 19 = CZ	39646.4
18	ZONE 25	.80	ZONE 23	2348.9
19	ZONE 21	.90	ZONE 23	3282.3
20	ZONE 22	.90	ZONE 23	6501.0

TABLE B10.1 (Cont.)

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
21	ZONE 23	.85	ZONE 1	51362.5
22	ZONE 26A	.90	ZONE 19 = CZ	246138.9
23	ZONE 27	.90	ZONE 19 = CZ	210047.1
24	ZONE 28	.90	ZONE 19 = CZ	187013.1
25	ZONE 28A	.80	ZONE 28	20689.1
26	ZONE 29	.70	ZONE 19 = CZ	249905.6
27	ZONE 32	.70	ZONE 19 = CZ	94290.4
28	ZONE 4A	.80	ZONE 19 = CZ	13665.6
29	ZONE 19 = CZ	1.00		7560144.1
30	ZONE 12B	1.00		27812.3
31	ZONE 24	1.00		289342.7
32	ZONE 26C	1.00		9564.3
33	ZONE 26B	1.00		5702.6
34	ZONE 30	1.00		61956.4
35	ZONE 31	1.00		31025.6

TABLE B10.2

Expert 10
LIST OF ALTERNATIVE ZONES OR CLUSTERS OF BOUNDARY ZONES

CLUSTER INDEX	WEIGHT	BACK	OLD/NEW	ZONES IN CLUSTER				
1	.600	Zone 19		Zone 12A	Zone 13			
	.400			Zone 12B	Zone 30	Zone 31		
2	.600	Zone 19		Zone 9	Zone 10	Zone 26A	Zone 27	
	.400			Zone 26C	Zone 26B			
3	.600	Zone 19		Zone 20	Zone 1	Zone 21	Zone 22	Zone 23
	.400			Zone 24				

TABLE B10.3

SEISMICITY DATA FOR EXPERT 10

```
NO. OF ZONES= 35     SELF WEIGHTS ARE 10.0  8.0  9.0  8.0   LLNL MODEL             NO      CORRELATION
*****************************************************************************************************
SEQ. #  1     LOC IN REG NO  1                     ******** MAP ZONE NAME =ZONE  1
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75       6.75
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                        UPPER LIMIT
UP MAG CO                         6.3                           6.0                                 6.8
    A                             3.050                         2.900                               3.170
    B                             -.950                        -1.100                               -.900
*****************************************************************************************************
SEQ. #  2     LOC IN REG NO  1                     ******** MAP ZONE NAME =ZONE  2
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75       6.00
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                        UPPER LIMIT
UP MAG CO                         5.5                           5.3                                 6.0
    A                             2.450                         2.300                               2.600
    B                             -.900                        -1.100                               -.900
*****************************************************************************************************
SEQ. #  3     LOC IN REG NO  1                     ******** MAP ZONE NAME =ZONE  3
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75       6.00
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                        UPPER LIMIT
UP MAG CO                         5.5                           5.3                                 6.0
    A                             3.040                         2.920                               3.160
    B                            -1.090                        -1.100                               -.900
*****************************************************************************************************
SEQ. #  4     LOC IN REG NO  2                     ******** MAP ZONE NAME =ZONE  4
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75       6.75
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                        UPPER LIMIT
UP MAG CO                         6.0                           5.8                                 6.8
    A                             3.500                         3.400                               3.690
    B                            -1.000                        -1.100                               -.900
*****************************************************************************************************
SEQ. #  5     LOC IN REG NO  2                     ******** MAP ZONE NAME =ZONE  5
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75       6.00
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                        UPPER LIMIT
UP MAG CO                         5.5                           5.3                                 6.0
    A                             2.520                         2.350                               2.700
    B                             -.820                        -1.000                               -.800
                     ***********  SEISMICITY DATA FOR EXPERT 10      **********
```

TABLE B10.3 (Cont.)

```
*******************************************************************************************
SEQ. # 6     LOC IN REG NO  1                ******** MAP ZONE NAME =ZONE  6
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF     (A-B*M)   MODEL IS        3.75      6.75
PARAMETER                     BEST ESTIMATE                LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          6.3                          6.0                         6.8
    A                              3.120                        3.000                       3.300
    B                              -.960                       -1.000                       -.900
*******************************************************************************************
SEQ. # 7     LOC IN REG NO  1                ******** MAP ZONE NAME =ZONE  7
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF     (A-B*M)   MODEL IS        3.75      7.00
PARAMETER                     BEST ESTIMATE                LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          6.5                          6.3                         7.0
    A                              3.480                        3.350                       3.700
    B                              -.920                       -1.000                       -.900
*******************************************************************************************
SEQ. # 8     LOC IN REG NO  1                ******** MAP ZONE NAME =ZONE  8
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF     (A-B*M)   MODEL IS        3.75      7.25
PARAMETER                     BEST ESTIMATE                LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          7.0                          6.8                         7.3
    A                              2.720                        2.500                       2.900
    B                              -.760                        -.800                       -.700
*******************************************************************************************
SEQ. # 9     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE  9
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF     (A-B*M)   MODEL IS        3.75      6.50
PARAMETER                     BEST ESTIMATE                LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          6.0                          5.8                         6.5
    A                              1.730                        1.600                       1.900
    B                              -.780                        -.900                       -.700
*******************************************************************************************
SEQ. # 10    LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 10
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF     (A-B*M)   MODEL IS        3.75      6.50
PARAMETER                     BEST ESTIMATE                LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          6.0                          5.8                         6.5
    A                              2.620                        2.500                       2.800
    B                             -1.000                       -1.100                       -.900
                    ***********  SEISMICITY DATA FOR EXPERT 10      **********
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TABLE B10.3 (Cont.)

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*************************************************************************************************************
SEQ. # 11     LOC IN REG NO  4                      ******** MAP ZONE NAME =ZONE 12A
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       7.25
PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                      UPPER LIMIT
UP MAG CO                         7.3                          7.0                              7.3
    A                             3.410                        3.300                            3.600
    B                             -.870                       -1.000                            -.800
*************************************************************************************************************
SEQ. # 12     LOC IN REG NO  4                      ******** MAP ZONE NAME =ZONE 12B
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       7.25
PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                      UPPER LIMIT
UP MAG CO                         7.3                          7.0                              7.3
    A                             3.590                        3.450                            3.800
    B                             -.900                       -1.000                            -.800
*************************************************************************************************************
SEQ. # 13     LOC IN REG NO  4                      ******** MAP ZONE NAME =ZONE 13
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       6.75
PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                      UPPER LIMIT
UP MAG CO                         6.3                          6.0                              6.8
    A                             4.200                        4.000                            4.400
    B                            -1.060                       -1.100                            -.900
*************************************************************************************************************
SEQ. # 14     LOC IN REG NO  2                      ******** MAP ZONE NAME =ZONE 15
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       7.25
PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                      UPPER LIMIT
UP MAG CO                         7.0                          6.8                              7.3
    A                             1.750                        1.600                            2.000
    B                             -.700                        -.900                            -.700
*************************************************************************************************************
SEQ. # 15     LOC IN REG NO  1                      ******** MAP ZONE NAME =ZONE 16
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75       6.75
PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                      UPPER LIMIT
UP MAG CO                         6.3                          6.0                              6.8
    A                             2.820                        2.600                            3.000
    B                             -.850                        -.900                            -.700
                         **********  SEISMICITY DATA FOR EXPERT 10      **********
```

TABLE B10.3 (Cont.)

```
**************************************************************************************
SEQ. # 16      LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 17
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS       3.75      7.25
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          7.3                          7.0                         7.5
    A                            1.690                        1.500                       1.900
    B                            -.570                        -.800                       -.550
**************************************************************************************
SEQ. # 17      LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 18
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS       3.75      7.25
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          7.3                          7.0                         7.5
    A                            1.690                        1.520                       1.860
    B                            -.570                        -.670                       -.470
**************************************************************************************
SEQ. # 18      LOC IN REG NO  3              ******** MAP ZONE NAME =ZONE 19 = CZ
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS       3.75      6.00
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          5.5                          5.3                         6.0
    A                            4.900                        4.800                       5.000
    B                           -1.000                       -1.100                       -.900
**************************************************************************************
SEQ. # 19      LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 20
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS       3.75      6.75
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          6.3                          6.0                         6.8
    A                            1.640                        1.500                       1.800
    B                            -.720                        -.900                       -.700
**************************************************************************************
SEQ. # 20      LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 21
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS       3.75      6.75
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          6.3                          6.0                         6.8
    A                            1.750                        1.600                       1.900
    B                            -.760                        -.900                       -.700
                    ***********  SEISMICITY DATA FOR EXPERT 10      **********
```

TABLE B10.3 (Cont.)

```
******************************************************************************************
SEQ. # 21     LOC IN REG NO  1                ******** MAP ZONE NAME =ZONE 22
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF     (A-B*M)   MODEL IS       3.75      6.25
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          6.3                          6.0                            6.8
    A                             1.200                        1.100                          1.400
    B                             -.700                        -.900                          -.700
******************************************************************************************
SEQ. # 22     LOC IN REG NO  1                ******** MAP ZONE NAME =ZONE 23
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF     (A-B*M)   MODEL IS       3.75      6.75
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          6.3                          6.0                            6.8
    A                             2.840                        2.700                          3.000
    B                             -.920                       -1.100                          -.900
******************************************************************************************
SEQ. # 23     LOC IN REG NO  1                ******** MAP ZONE NAME =ZONE 24
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF     (A-B*M)   MODEL IS       3.75      6.75
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          6.3                          6.0                            6.8
    A                             3.640                        3.500                          3.800
    B                            -1.000                       -1.100                          -.900
******************************************************************************************
SEQ. # 24     LOC IN REG NO  1                ******** MAP ZONE NAME =ZONE 25
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF     (A-B*M)   MODEL IS       3.75      6.75
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          6.3                          6.0                            6.8
    A                             1.600                        1.400                          1.800
    B                             -.760                        -.900                          -.700
******************************************************************************************
SEQ. # 25     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 26A
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF     (A-B*M)   MODEL IS       3.75      5.75
PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                    UPPER LIMIT
UP MAG CO                          6.0                          5.8                            6.5
    A                             3.230                        3.100                          3.400
    B                             -.940                       -1.100                          -.900
                   ***********  SEISMICITY DATA FOR EXPERT 10      **********
```

TABLE B10.3 (Cont.)

```
*****************************************************************************************************
SEQ. # 26     LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 26A
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS         3.75       6.50

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.0                         5.8                          6.5
    A                              2.120                       2.000                        2.300
    B                              -.760                       -.900                        -.700
*****************************************************************************************************
SEQ. # 27     LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 26B
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS         3.75       6.50

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.0                         5.8                          6.5
    A                              1.450                       1.300                        1.620
    B                              -.800                       -.900                        -.700
*****************************************************************************************************
SEQ. # 28     LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 27
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS         3.75       6.00

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          5.5                         5.3                          6.0
    A                              2.440                       2.300                        2.600
    B                             -1.000                      -1.100                        -.900
*****************************************************************************************************
SEQ. # 29     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 28
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS         3.75       6.75

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.3                         6.0                          6.8
    A                              3.380                       3.200                        3.500
    B                              -.920                      -1.100                        -.900
*****************************************************************************************************
SEQ. # 30     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 28A
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS         3.75       6.75

PARAMETER                     BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.3                         6.0                          6.8
    A                              2.610                       2.500                        2.800
    B                              -.890                      -1.000                        -.800
                          ***********  SEISMICITY DATA FOR EXPERT 10      **********
```

TABLE B10.3 (Cont.)

```
****************************************************************************************************
SEQ. # 31      LOC IN REG NO  4                     ******** MAP ZONE NAME =ZONE 29
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75       6.75
PARAMETER                        BEST ESTIMATE                  LOWER LIMIT                 UPPER LIMIT
UP MAG CO                             6.3                           6.0                          6.8
    A                                 3.190                         3.100                        3.400
    B                                 -.900                        -1.000                        -.800
****************************************************************************************************
SEQ. # 32      LOC IN REG NO  4                     ******** MAP ZONE NAME =ZONE 30
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75       6.75
PARAMETER                        BEST ESTIMATE                  LOWER LIMIT                 UPPER LIMIT
UP MAG CO                             6.3                           6.0                          6.8
    A                                 3.140                         3.100                        3.400
    B                                 -.900                        -1.000                        -.800
****************************************************************************************************
SEQ. # 33      LOC IN REG NO  4                     ******** MAP ZONE NAME =ZONE 31
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75       6.75
PARAMETER                        BEST ESTIMATE                  LOWER LIMIT                 UPPER LIMIT
UP MAG CO                             6.3                           6.0                          6.8
    A                                 3.060                         2.900                        3.200
    B                                 -.900                        -1.000                        -.800
****************************************************************************************************
SEQ. # 34      LOC IN REG NO  4                     ******** MAP ZONE NAME =ZONE 32
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75       6.75
PARAMETER                        BEST ESTIMATE                  LOWER LIMIT                 UPPER LIMIT
UP MAG CO                             6.3                           6.0                          6.8
    A                                 2.850                         2.700                        3.000
    B                                 -.900                        -1.000                        -.800
****************************************************************************************************
SEQ. # 35      LOC IN REG NO  1                     ******** MAP ZONE NAME =ZONE 4A
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS          3.75       6.75
PARAMETER                        BEST ESTIMATE                  LOWER LIMIT                 UPPER LIMIT
UP MAG CO                             6.0                           5.8                          6.8
    A                                 2.000                         1.840                        2.190
    B                                -1.000                        -1.100                        -.900
****************************************************************************************************
                  ********* END OF SEISMICITY DATA FOR EXPERT 10    ZONES *****

    EXPERT'S RELATION BETWEEN I(MAX) & MB IS
    I(MAX)=  1.49*MB  -.66
```

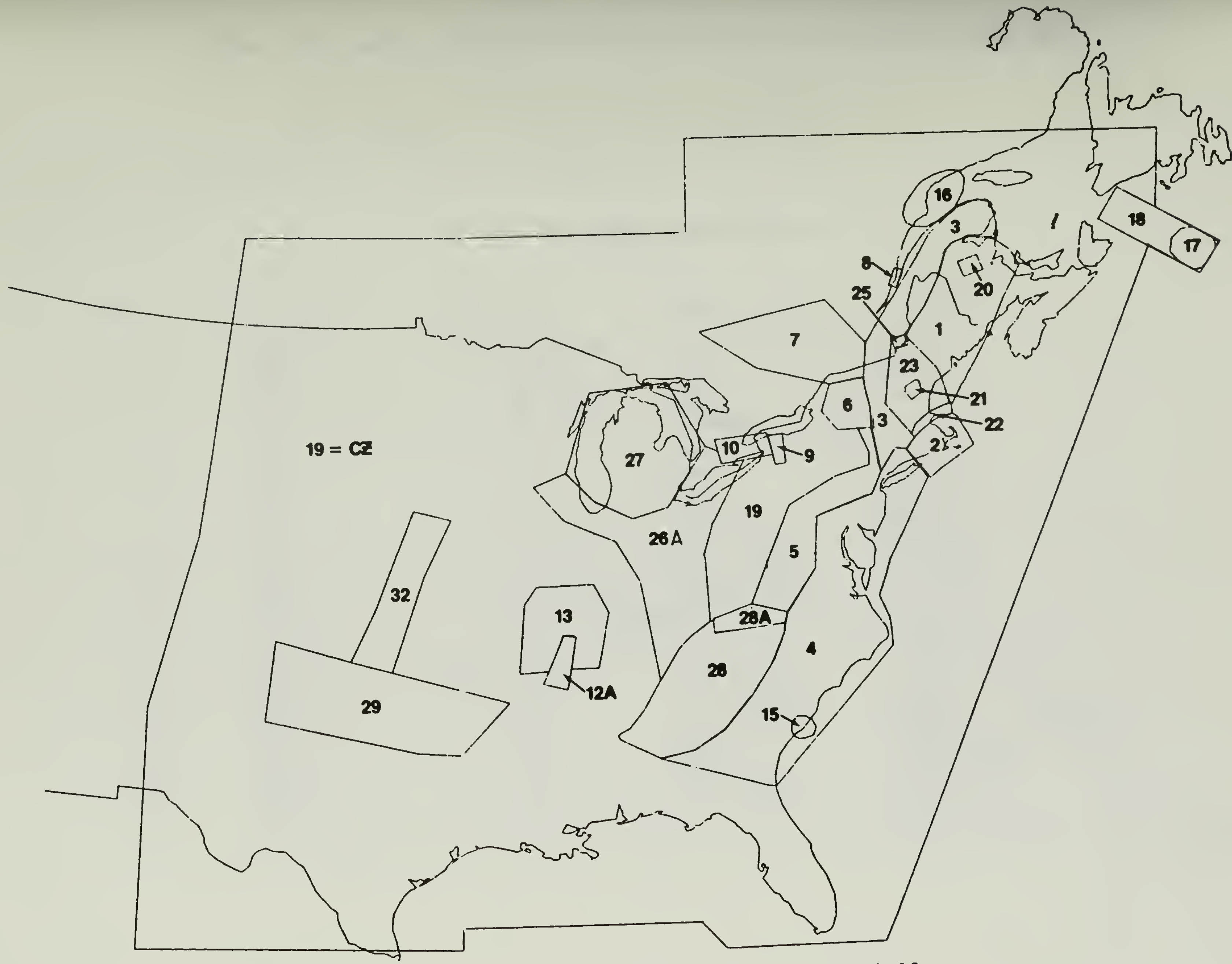

Figure B10.1 Seismic zonation base map for Expert 10.

Figure B10.2 Map of alternative seismic zonations to Expert 10's base map.

TABLE B11.1

INFORMATION ABOUT ZONES DEFINED
BY EXPERT 11

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 1	.80	CZ = ZONE 19	210566.3
2	ZONE 2	.90	ZONE 3	104861.0
3	ZONE 3	.95	ZONE 2	89479.1
4	ZONE 4	.50	CZ = ZONE 19	15440.0
5	ZONE 5	.80	ZONE 6	111032.7
6	ZONE 6	1.00		140552.0
7	ZONE 7	1.00		156525.6
8	ZONE 8	.90	CZ = ZONE 19	445251.3
9	ZONE 9	.80	CZ = ZONE 19	110795.0
10	ZONE 10	.90	CZ = ZONE 19	188505.4
11	ZONE 11	1.00		41822.8
12	ZONE 12	.80	CZ = ZONE 19	16890.7
13	ZONE 13	.90	CZ = ZONE 19	74450.1
14	ZONE 14	.90	CZ = ZONE 19	624214.0
15	ZONE 15	.95	CZ = ZONE 19	80359.5
16	ZONE 16	.90	ZONE 15	106271.0
17	ZONE 17	.70	CZ = ZONE 19	286132.9
18	ZONE 18	.80	CZ = ZONE 19	235835.2
19	CZ = ZONE 19	1.00		6850925.2

TABLE B11.3

SEISMICITY DATA FOR EXPERT 11

```
NO. OF ZONES= 21      SELF WEIGHTS ARE  8.0 10.0  6.0  6.0   LLNL MODEL            NO      CORRELATION
**********************************************************************************************************
SEQ. #  1     LOC IN REG NO  1                  ******** MAP ZONE NAME =ZONE  1
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS         3.75      5.75
PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          5.8                            5.4                           6.1
    A                              3.750                          3.600                         3.900
    B                             -1.000                         -1.200                         -.600
**********************************************************************************************************
SEQ. #  2     LOC IN REG NO  1                  ******** MAP ZONE NAME =ZONE  2
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS         3.75      5.75
PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          5.8                            5.4                           6.1
    A                              3.400                          3.300                         3.500
    B                              -.900                         -1.200                         -.700
**********************************************************************************************************
SEQ. #  3     LOC IN REG NO  1                  ******** MAP ZONE NAME =ZONE  3
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS         3.75      7.00
PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          7.0                            6.7                           7.4
    A                              2.300                          2.200                         2.400
    B                              -.600                          -.800                         -.500
**********************************************************************************************************
SEQ. #  4     LOC IN REG NO  1                  ******** MAP ZONE NAME =ZONE  4
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS         3.75      6.50
PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          6.5                            6.2                           7.0
    A                              2.000                          1.800                         2.700
    B                              -.800                         -1.300                         -.600
**********************************************************************************************************
SEQ. #  5     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE  5
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS         3.75      6.50
PARAMETER                      BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          6.5                            6.2                           7.0
    A                              3.700                          3.600                         3.900
    B                             -1.000                         -1.300                         -.800
                        ***********  SEISMICITY DATA FOR EXPERT 11      **********
```

TABLE B11.3 (Cont.)

****

SEQ. # 6 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 6A
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	6.2	7.0
A	4.000	3.500	4.200
B	-1.000	-1.300	-.800

****

SEQ. # 7 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 6B
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.5	6.2	7.0
A	2.750	2.000	2.900
B	-1.000	-1.300	-.800

****

SEQ. # 8 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 7A
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	5.4	6.1
A	3.750	3.500	3.950
B	-1.000	-1.200	-.800

****

SEQ. # 9 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 7B
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 5.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.8	5.4	6.1
A	2.500	1.800	2.800
B	-1.000	-1.200	-.800

****

SEQ. # 10 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 8
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 7.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.0	6.7	7.4
A	2.250	2.050	2.500
B	-.700	-1.200	-.500

*********** SEISMICITY DATA FOR EXPERT 11 **********

TABLE B11.3 (Cont.)

```
******************************************************************************************
SEQ. # 11     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE  9
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       5.00
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.5                           6.0                          6.8
    A                             3.650                         3.350                        3.750
    B                            -1.000                        -1.200                        -.700
******************************************************************************************
SEQ. # 12     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 10
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       6.50
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         6.5                           6.0                          6.8
    A                             3.600                         3.400                        3.800
    B                             -.900                        -1.200                        -.800
******************************************************************************************
SEQ. # 13     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 11
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       7.00
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         7.0                           6.7                          7.4
    A                             2.700                         2.400                        3.000
    B                             -.800                        -1.000                        -.400
******************************************************************************************
SEQ. # 14     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 12
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       5.50
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         5.8                           5.4                          6.1
    A                             2.900                         2.700                        3.100
    B                            -1.000                        -1.300                        -.800
******************************************************************************************
SEQ. # 15     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 13
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75       5.75
PARAMETER                    BEST ESTIMATE                  LOWER LIMIT                  UPPER LIMIT
UP MAG CO                         5.8                           5.4                          6.1
    A                             2.000                         1.300                        2.300
    B                             -.800                        -1.300                        -.600
                    ***********  SEISMICITY DATA FOR EXPERT 11      **********
```

TABLE B11.3 (Cont.)

```
****************************************************************************************************
SEQ. # 16     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 14
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75       5.00

PARAMETER                       BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                           5.8                            5.4                           6.1
    A                               4.370                          4.000                         4.500
    B                              -1.200                         -1.400                         -.900
****************************************************************************************************
SEQ. # 17     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 15
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75       6.50

PARAMETER                       BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                           6.5                            6.2                           7.0
    A                               2.600                          2.500                         2.750
    B                               -.800                         -1.100                         -.500
****************************************************************************************************
SEQ. # 18     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 16
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75       5.75

PARAMETER                       BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                           6.5                            6.0                           6.8
    A                               3.350                          3.150                         3.600
    B                              -1.000                         -1.200                         -.800
****************************************************************************************************
SEQ. # 19     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 17
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75       5.75

PARAMETER                       BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                           5.8                            5.4                           6.1
    A                               3.600                          3.000                         3.850
    B                              -1.000                         -1.100                         -.900
****************************************************************************************************
SEQ. # 20     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 18
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        3.75       5.75

PARAMETER                       BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                           5.8                            5.4                           6.1
    A                               3.350                          3.200                         3.500
    B                              -1.000                         -1.200                         -.700
                            ***********  SEISMICITY DATA FOR EXPERT 11      **********
```

TABLE B11.3 (Cont.)

```
****************************************************************************************************
SEQ. # 21     LOC IN REG NO  3              ******** MAP ZONE NAME =19-C.Z.
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       3.75      5.75

PARAMETER                      BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          5.8                           5.5                         6.3
    A                            4.250                         4.050                       4.450
    B                            -.900                        -1.000                       -.800
****************************************************************************************************

                  ********* END OF SEISMICITY DATA FOR EXPERT 11    ZONES *****

     EXPERT'S RELATION BETWEEN I(MAX) & MB IS
     I(MAX)=  2.00*MB -3.50
```

Figure B11.1 Seismic zonation base map for Expert 11.

TABLE B12.1

INFORMATION ABOUT ZONES DEFINED
BY EXPERT 12

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 1	.90	ZONE 40	128666.9
2	ZONE 3	1.00		130941.5
3	ZONE 5	.65	ZONE 4 = CZ	309185.0
4	ZONE 6	.60	ZONE 4 = CZ	50083.5
5	ZONE 7	.60	ZONE 4 = CZ	21889.4
6	ZONE 8	.70	ZONE 4 = CZ	90006.8
7	ZONE 10	1.00		701677.7
8	ZONE 11	.50	ZONE 12	116535.7
9	ZONE 12	.70	ZONE 13	83926.9
10	ZONE 15	.80	ZONE 13	8654.8
11	ZONE 14	.80	ZONE 13	24089.8
12	ZONE 13	1.00		103054.1
13	ZONE 16	.60	ZONE 19	36932.2
14	ZONE 17	.70	ZONE 4 = CZ	79072.7
15	ZONE 18	.50	ZONE 4 = CZ	33132.4
16	ZONE 19	1.00		95229.2
17	ZONE 20	1.00		45254.9
18	ZONE 21	1.00		61967.7
19	ZONE 22	.70	ZONE 32	147987.7
20	ZONE 23A	.70	ZONE 23	5091.9

TABLE B12.1 (Cont.)

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
21	ZONE 23	1.00		53816.3
22	ZONE 24	.60	ZONE 23	36435.6
23	ZONE 25	1.00		384478.1
24	ZONE 26	1.00		547215.4
25	ZONE 27	.80	ZONE 32	93948.5
26	ZONE 30	.80	ZONE 4 = CZ	44684.8
27	ZONE 31	1.00		146238.6
28	ZONE 31A	.80	ZONE 31	51661.9
29	ZONE 33	.90	ZONE 32	31358.6
30	ZONE 38	.80	ZONE 32	148791.5
31	ZONE 32	1.00		589276.9
32	ZONE 34	1.00		12151.5
33	ZONE 35	1.00		46921.9
34	ZONE 36	1.00		209142.8
35	ZONE 37	.70	ZONE 25	48820.7
36	ZONE 39	.90	ZONE 25	24526.9
37	ZONE 40	1.00		342667.5
38	ZONE 41	1.00		727416.4
39	ZONE 4 = CZ	1.00		3835147.3
40	ZONE 2	.20	ZONE 4 = CZ	443342.2

TABLE B12.1 (Cont.)

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
41	ZONE 9	.30	ZONE 4 = CZ	30293.6
42	ZONE 28	.40	ZONE 4 = CZ	15564.8
43	ZONE 29	.30	ZONE 4 = CZ	32175.9

TABLE B12.3

```
                                    SEISMICITY DATA FOR EXPERT 12

NO. OF ZONES= 43     SELF WEIGHTS ARE   .9   .9   .9   .9   TRUNCATED EXPONETIAL  NO      CORRELATION
*********************************************************************************************************
SEQ. #  1     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE  1
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00       0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                         6.8                           6.5                           7.3
    A                             3.550                         2.850                         4.250
    B                            -1.100                        -1.150                        -1.000
*********************************************************************************************************
SEQ. #  2     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE  2
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00       0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                         5.0                           4.8                           5.5
    A                             3.500                         2.800                         4.200
    B                            -1.150                        -1.200                        -1.100
*********************************************************************************************************
SEQ. #  3     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE  3
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00       0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                         7.2                           7.0                           7.5
    A                             3.900                         3.200                         4.600
    B                            -1.100                        -1.150                        -1.000
*********************************************************************************************************
SEQ. #  4     LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE  5
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00       0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                         6.0                           5.8                           6.3
    A                             3.650                         2.950                         4.350
    B                            -1.150                        -1.200                        -1.100
*********************************************************************************************************
SEQ. #  5     LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE  6
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00       0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                         6.0                           5.8                           6.3
    A                             3.300                         2.600                         4.000
    B                            -1.150                        -1.200                        -1.100
                          ***********  SEISMICITY DATA FOR EXPERT 12     **********
```

Expert 12 used only the truncated exponential recurrence model for which no range for linearity was needed. Hence Expert 12 did not provide bounds of magnitude where the model is linear, and these bounds in Table B12.3 which appear as 0.00 are not used in the analysis.

TABLE B12.3 (Cont.)

```
***************************************************************************************************
SEQ. #  6      LOC IN REG NO  3                   ******** MAP ZONE NAME =ZONE  7
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS          0.00       0.00

PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                             5.8                           5.6                           6.1
    A                                 3.750                         3.050                         4.450
    B                                -1.150                        -1.200                        -1.100
***************************************************************************************************
SEQ. #  7      LOC IN REG NO  4                   ******** MAP ZONE NAME =ZONE  8
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS          0.00       0.00

PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                             6.0                           5.8                           6.3
    A                                 3.320                         2.620                         4.020
    B                                -1.100                        -1.150                        -1.000
***************************************************************************************************
SEQ. #  8      LOC IN REG NO  4                   ******** MAP ZONE NAME =ZONE  9
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS          0.00       0.00

PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                             5.5                           5.2                           5.8
    A                                 3.500                         2.800                         4.200
    B                                -1.100                        -1.150                        -1.000
***************************************************************************************************
SEQ. #  9      LOC IN REG NO  4                   ******** MAP ZONE NAME =ZONE 10
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS          0.00       0.00

PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                             5.0                           4.8                           5.2
    A                                 2.870                         2.170                         3.570
    B                                 -.950                        -1.050                         -.850
***************************************************************************************************
SEQ. # 10      LOC IN REG NO  4                   ******** MAP ZONE NAME =ZONE 11
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS          0.00       0.00

PARAMETER                         BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                             5.5                           5.3                           5.8
    A                                 3.000                         2.300                         3.700
    B                                -1.100                        -1.150                        -1.000
                         ***********  SEISMICITY DATA FOR EXPERT 12      **********
```

Expert 12 used only the truncated exponential recurrence model for which no range for linearity was needed. Hence Expert 12 did not provide bounds of magnitude where the model is linear, and these bounds in Table B12.3 which appear as 0.00 are not used in the analysis.

TABLE B12.3 (Cont.)

```
********************************************************************************************
SEQ. # 11     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 12
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        0.00       0.00
PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          5.8                         5.5                            6.1
    A                            3.000                       2.300                          3.700
    B                           -1.100                      -1.150                         -1.000
********************************************************************************************
SEQ. # 12     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 15
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        0.00       0.00
PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          7.5                         7.3                            7.8
    A                            3.640                       2.940                          4.340
    B                           -1.100                      -1.150                         -1.000
********************************************************************************************
SEQ. # 13     LOC IN REG NO  4                ******** MAP ZONE NAME =ZONE 14
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        0.00       0.00
PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          6.8                         6.6                            7.1
    A                            3.680                       2.980                          4.380
    B                           -1.100                      -1.150                         -1.000
********************************************************************************************
SEQ. # 14     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 13
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        0.00       0.00
PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          6.2                         6.0                            6.5
    A                            4.030                       3.330                          4.730
    B                           -1.100                      -1.150                         -1.000
********************************************************************************************
SEQ. # 15     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 16
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)    MODEL IS        0.00       0.00
PARAMETER                    BEST ESTIMATE                 LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          5.5                         5.3                            5.8
    A                            3.000                       2.300                          3.700
    B                           -1.100                      -1.150                         -1.000
                        ***********  SEISMICITY DATA FOR EXPERT 12      **********
```

Expert 12 used only the truncated exponential recurrence model for which no range for linearity was needed. Hence Expert 12 did not provide bounds of magnitude where the model is linear, and these bounds in Table B12.3 which appear as 0.00 are not used in the analysis.

TABLE B12.3 (Cont.)

```
****************************************************************************************************
SEQ. # 16     LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE 17
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00      0.00

PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                              5.5                          5.3                         5.8
    A                                  3.530                        2.830                       4.230
    B                                 -1.100                       -1.150                      -1.000
****************************************************************************************************
SEQ. # 17     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 18
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00      0.00

PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                              5.2                          4.9                         5.5
    A                                  2.680                        1.980                       3.380
    B                                 -1.100                       -1.150                      -1.000
****************************************************************************************************
SEQ. # 18     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 19
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00      0.00

PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                              6.0                          5.8                         6.3
    A                                  3.760                        3.060                       4.460
    B                                 -1.100                       -1.150                      -1.000
****************************************************************************************************
SEQ. # 19     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 20
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00      0.00

PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                              6.2                          6.0                         6.3
    A                                  3.380                        2.680                       4.080
    B                                 -1.100                       -1.150                      -1.000
****************************************************************************************************
SEQ. # 20     LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE 21
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00      0.00

PARAMETER                        BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                              5.8                          5.6                         6.1
    A                                  2.830                        2.130                       3.530
    B                                 -1.100                       -1.150                      -1.000
                          ***********  SEISMICITY DATA FOR EXPERT 12      **********
```

Expert 12 used only the truncated exponential recurrence model for which no range for linearity was needed. Hence Expert 12 did not provide bounds of magnitude where the model is linear, and these bounds in Table B12.3 which appear as 0.00 are not used in the analysis.

TABLE B12.3 (Cont.)

```
****************************************************************************************************
SEQ. # 21     LOC IN REG NO  2                 ******** MAP ZONE NAME =ZONE 22
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00       0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                     UPPER LIMIT
UP MAG CO                          5.4                          5.1                              5.7
    A                            3.430                        2.730                            4.130
    B                           -1.100                       -1.150                           -1.000
****************************************************************************************************
SEQ. # 22     LOC IN REG NO  2                 ******** MAP ZONE NAME =ZONE 23A
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00       0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                     UPPER LIMIT
UP MAG CO                          6.9                          6.8                              7.0
    A                            2.550                        1.850                            3.250
    B                            -.900                       -1.000                            -.800
****************************************************************************************************
SEQ. # 23     LOC IN REG NO  2                 ******** MAP ZONE NAME =ZONE 23
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00       0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                     UPPER LIMIT
UP MAG CO                          6.0                          5.7                              6.2
    A                            1.960                        1.260                            2.660
    B                            -.900                       -1.000                            -.800
****************************************************************************************************
SEQ. # 24     LOC IN REG NO  2                 ******** MAP ZONE NAME =ZONE 24
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00       0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                     UPPER LIMIT
UP MAG CO                          6.0                          5.7                              6.2
    A                            1.730                        1.030                            2.430
    B                            -.900                       -1.000                            -.800
****************************************************************************************************
SEQ. # 25     LOC IN REG NO  2                 ******** MAP ZONE NAME =ZONE 25
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00       0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                     UPPER LIMIT
UP MAG CO                          6.1                          5.7                              6.3
    A                            1.680                         .980                            2.380
    B                            -.900                       -1.000                            -.800
                    ***********  SEISMICITY DATA FOR EXPERT 12       **********
```

Expert 12 used only the truncated exponential recurrence model for which no range for linearity was needed. Hence Expert 12 did not provide bounds of magnitude where the model is linear, and these bounds in Table B12.3 which appear as 0.00 are not used in the analysis.

TABLE B12.3 (Cont.)

```
*******************************************************************************************
SEQ. # 26     LOC IN REG NO  2                ******** MAP ZONE NAME =ZONE 26
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00      0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          4.7                          4.5                          5.0
    A                              3.410                        2.710                        4.110
    B                             -1.150                       -1.250                       -1.000
*******************************************************************************************
SEQ. # 27     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 27
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00      0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          5.5                          5.2                          5.8
    A                              3.130                        2.430                        3.850
    B                             -1.100                       -1.150                       -1.000
*******************************************************************************************
SEQ. # 28     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 28
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00      0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          5.4                          5.0                          5.8
    A                              3.190                        2.490                        3.890
    B                             -1.100                       -1.150                       -1.000
*******************************************************************************************
SEQ. # 29     LOC IN REG NO  3                ******** MAP ZONE NAME =ZONE 29
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00      0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          5.4                          5.0                          5.8
    A                              3.500                        2.800                        4.200
    B                             -1.100                       -1.150                       -1.000
*******************************************************************************************
SEQ. # 30     LOC IN REG NO  1                ******** MAP ZONE NAME =ZONE 30
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00      0.00

PARAMETER                     BEST ESTIMATE                 LOWER LIMIT                 UPPER LIMIT
UP MAG CO                          5.5                          5.0                          6.0
    A                              3.050                        2.350                        3.750
    B                             -1.000                       -1.050                        -.950
                         ***********  SEISMICITY DATA FOR EXPERT 12      **********
```

Expert 12 used only the truncated exponential recurrence model for which no range for linearity was needed. Hence Expert 12 did not provide bounds of magnitude where the model is linear, and these bounds in Table B12.3 which appear as 0.00 are not used in the analysis.

TABLE B12.3 (Cont.)

```
******************************************************************************************
SEQ. # 31     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 31
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00       0.00

PARAMETER                          BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                              6.5                         6.0                          6.8
    A                                  4.400                       2.700                        5.100
    B                                 -1.050                      -1.100                       -1.000
******************************************************************************************
SEQ. # 32     LOC IN REG NO  3              ******** MAP ZONE NAME =ZONE 31A
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00       0.00

PARAMETER                          BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                              6.5                         6.0                          6.8
    A                                  3.920                       3.220                        4.620
    B                                 -1.050                      -1.100                       -1.000
******************************************************************************************
SEQ. # 33     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 33
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00       0.00

PARAMETER                          BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                              6.0                         5.5                          6.5
    A                                  3.430                       2.730                        4.130
    B                                 -1.100                      -1.150                       -1.000
******************************************************************************************
SEQ. # 34     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 38
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00       0.00

PARAMETER                          BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                              6.1                         5.8                          6.5
    A                                  3.600                       2.400                        4.300
    B                                 -1.100                      -1.150                       -1.000
******************************************************************************************
SEQ. # 35     LOC IN REG NO  1              ******** MAP ZONE NAME =ZONE 32
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS       0.00       0.00

PARAMETER                          BEST ESTIMATE               LOWER LIMIT                 UPPER LIMIT
UP MAG CO                              6.0                         5.8                          6.3
    A                                  4.190                       3.490                        4.890
    B                                 -1.100                      -1.150                       -1.000
                      ***********  SEISMICITY DATA FOR EXPERT 12      **********
```

Expert 12 used only the truncated exponential recurrence model for which no range for linearity was needed. Hence Expert 12 did not provide bounds of magnitude where the model is linear, and these bounds in Table B12.3 which appear as 0.00 are not used in the analysis.

TABLE B12.3 (Cont.)

SEQ. # 36 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 34
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 0.00 0.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.1	7.0	7.2
A	3.190	2.490	3.890
B	-.900	-1.000	-.800

SEQ. # 37 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 35
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 0.00 0.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.2	5.7	6.5
A	3.870	3.170	4.570
B	-1.100	-1.150	-1.000

SEQ. # 38 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 36
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 0.00 0.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	5.0	4.5	5.3
A	3.070	2.370	3.770
B	-1.000	-1.100	-.900

SEQ. # 39 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 37
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 0.00 0.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.1	5.7	6.3
A	3.240	2.540	3.940
B	-1.100	-1.150	-1.000

SEQ. # 40 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 39
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 0.00 0.00

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.2	5.7	6.5
A	3.980	3.280	4.680
B	-1.100	-1.150	-1.000

*********** SEISMICITY DATA FOR EXPERT 12 **********

Expert 12 used only the truncated exponential recurrence model for which no range for linearity was needed. Hence Expert 12 did not provide bounds of magnitude where the model is linear, and these bounds in Table B12.3 which appear as 0.00 are not used in the analysis.

TABLE B12.3 (Cont.)

```
*****************************************************************************************************
SEQ. # 41     LOC IN REG NO  3                 ******** MAP ZONE NAME =ZONE 40
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00      0.00

PARAMETER                       BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                             6.5                           6.0                          7.0
     A                                3.300                         2.600                        4.000
     B                                -.900                        -1.000                        -.800
*****************************************************************************************************
SEQ. # 42     LOC IN REG NO  2                 ******** MAP ZONE NAME =ZONE 41
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00      0.00

PARAMETER                       BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                             4.5                           4.0                          5.0
     A                                3.070                         2.370                        3.770
     B                                -.900                        -1.000                        -.800
*****************************************************************************************************
SEQ. # 43     LOC IN REG NO  3                 ******** MAP ZONE NAME =ZONE 4 = CZ
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS        0.00      0.00

PARAMETER                       BEST ESTIMATE                 LOWER LIMIT                  UPPER LIMIT
UP MAG CO                             5.0                           4.8                          5.2
     A                                4.460                         3.760                        5.160
     B                               -1.150                        -1.200                       -1.100
*****************************************************************************************************
                    ********* END OF SEISMICITY DATA FOR EXPERT 12    ZONES *****

     EXPERT'S RELATION BETWEEN I(MAX) & MB IS
     I(MAX)=  2.00*MB -3.50
```

Expert 12 used only the truncated exponential recurrence model for which no range for linearity was needed. Hence Expert 12 did not provide bounds of magnitude where the model is linear, and these bounds in Table B12.3 which appear as 0.00 are not used in the analysis.

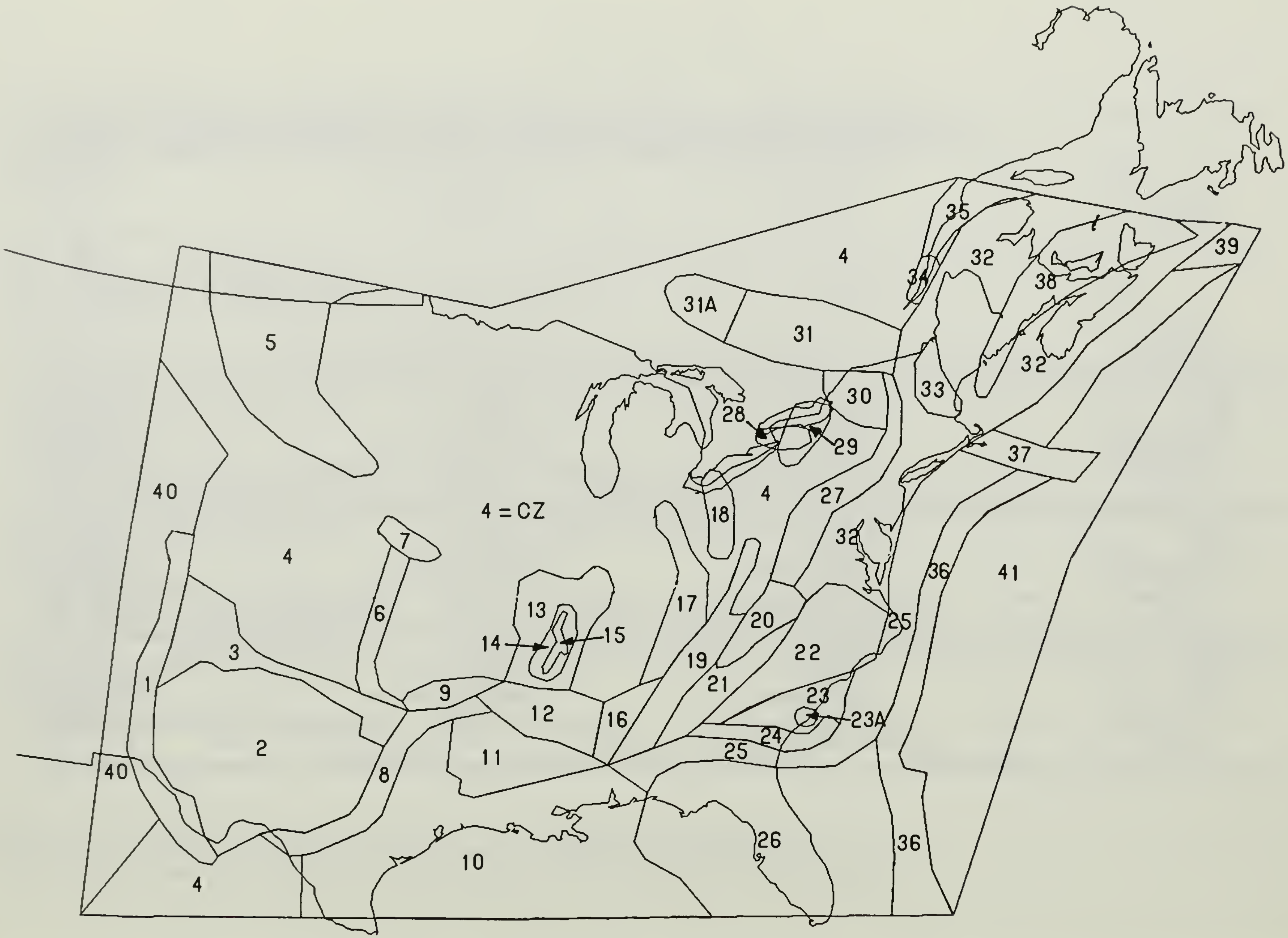

Figure B12.1 Seismic zonation base map for Expert 12.

TABLE B13.1

INFORMATION ABOUT ZONES DEFINED BY EXPERT 13

INDEX	EXPERT'S ZONE NAME	CONFIDENCE IN EXIST.	IF DOSEN'T EXIST BECOMES	AREA OF ZONE
1	ZONE 1	.90	CZ 15	143123.5
2	ZONE 3	.80	CZ 15	46998.6
3	ZONE 5	1.00		3079.3
4	ZONE 4	.90	ZONE 5	18806.0
5	ZONE 6	.60	CZ 15	35184.5
6	ZONE 7	.70	CZ 15	41192.5
7	ZONE 8	.85	CZ 15	158114.2
8	ZONE 9	.70	CZ 15	21063.2
9	ZONE 10	.60	CZ 15	70008.3
10	ZONE 11	.85	CZ 15	93691.8
11	ZONE 12	.85	CZ 15	18385.9
12	ZONE 18	.70	CZ 15	57028.5
13	CZ 16	.70	CZ 15	1637300.0
14	CZ 17	.60	CZ 15	475189.0
15	CZ 18	1.00		1124250.1
16	CZ 15	1.00		5946494.4
17	ZONE 2	.40	CZ 15	9973.0
18	ZONE 5	1.00		4334.8
19	ZONE 14	1.00		24932.3
20	ZONE 13	1.00		569990.4

TABLE B13.2

EXPERT 13

LIST OF ALTERNATIVE ZONES OR CLUSTERS OF BOUNDARY ZONES

CLUSTER INDEX	WEIGHT	BACK	OLD / NEW	ZONES IN CLUSTER				
1	.800	CZ 15		ZONE 4				
	.200			ZONE 14				
2	.750	CZ 15		ZONE 8	ZONE 1	ZONE 4	ZONE 9	ZONE 10
	.250			ZONE 14	ZONE 13			
3	.600	CZ 15		ZONE 5				
	.400			ZONE 5	ZONE 2			

TABLE B13.3

```
                                SEISMICITY DATA FOR EXPERT 13

NO. OF ZONES= 20     SELF WEIGHTS ARE  6.0  9.0  7.0  9.0   LLNL MODEL            NO      CORRELATION
*****************************************************************************************************
SEQ. #  1     LOC IN REG NO  4                 ******** MAP ZONE NAME =ZONE  1
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS         3.75       5.50

PARAMETER                      BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.5                          6.2                          6.8
    A                              3.890                        3.190                        4.590
    B                             -1.120                       -1.420                        -.820
*****************************************************************************************************
SEQ. #  2     LOC IN REG NO  4                 ******** MAP ZONE NAME =ZONE  2
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS         3.75       4.75

PARAMETER                      BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          7.0                          6.0                          7.3
    A                             -3.940                       -2.740                       -5.140
    B                             -1.170                       -1.370                        -.870
*****************************************************************************************************
SEQ. #  3     LOC IN REG NO  4                 ******** MAP ZONE NAME =ZONE  3
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS         3.75       5.00

PARAMETER                      BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.0                          5.6                          6.4
    A                              4.010                        3.300                        4.700
    B                             -1.170                       -1.370                        -.870
*****************************************************************************************************
SEQ. #  4     LOC IN REG NO  4                 ******** MAP ZONE NAME =ZONE  4
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS         3.75       5.50

PARAMETER                      BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          6.2                          6.0                          6.6
    A                              3.950                        3.250                        4.650
    B                             -1.090                       -1.390                        -.790
*****************************************************************************************************
SEQ. #  5     LOC IN REG NO  4                 ******** MAP ZONE NAME =ZONE  5
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF      (A-B*M)   MODEL IS         1.60       6.20

PARAMETER                      BEST ESTIMATE                LOWER LIMIT                  UPPER LIMIT
UP MAG CO                          7.4                          7.0                          7.5
    A                              3.270                        3.190                        3.350
    B                              -.890                        -.930                        -.850
                          **********  SEISMICITY DATA FOR EXPERT 13      **********
```

TABLE B13.3 (Cont.)

```
****************************************************************************************************
SEQ. #  6      LOC IN REG NO  4                  ******** MAP ZONE NAME =ZONE  6
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS         3.75       5.50

PARAMETER                     BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          6.2                          6.0                           6.6
    A                            3.030                        2.430                         3.630
    B                            -.910                       -1.210                         -.610
****************************************************************************************************
SEQ. #  7      LOC IN REG NO  3                  ******** MAP ZONE NAME =ZONE  7
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS         3.75       5.30

PARAMETER                     BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          5.8                          5.6                           6.0
    A                            2.250                        1.750                         2.750
    B                            -.830                       -1.130                         -.660
****************************************************************************************************
SEQ. #  8      LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE  8
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS         3.75       5.75

PARAMETER                     BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          6.3                          6.0                           6.3
    A                            4.270                        3.820                         4.720
    B                           -1.150                       -1.450                         -.850
****************************************************************************************************
SEQ. #  9      LOC IN REG NO  2                  ******** MAP ZONE NAME =ZONE  9
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS         3.75       6.75

PARAMETER                     BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          6.7                          6.6                           6.9
    A                            2.750                        2.050                         3.450
    B                            -.910                       -1.210                         -.610
****************************************************************************************************
SEQ. # 10      LOC IN REG NO  1                  ******** MAP ZONE NAME =ZONE 10
OCCURRENCE MODEL IN MAGNITUDE     LINEAR RANGE OF       (A-B*M)   MODEL IS         3.75       5.75

PARAMETER                     BEST ESTIMATE                  LOWER LIMIT                   UPPER LIMIT
UP MAG CO                          6.1                          5.8                           6.3
    A                            3.930                        3.430                         4.430
    B                           -1.130                       -1.430                         -.730
                    ***********  SEISMICITY DATA FOR EXPERT 13      **********
```

TABLE B13.3 (Cont.)

SEQ. # 11 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 11
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 6.05

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.3	6.0	6.6
A	4.510	3.910	5.110
B	-1.170	-1.470	-.870

SEQ. # 12 LOC IN REG NO 1 ******** MAP ZONE NAME =ZONE 12
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 6.50

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.0	6.7	7.4
A	2.510	1.860	3.160
B	-.770	-1.070	-.500

SEQ. # 13 LOC IN REG NO 2 ******** MAP ZONE NAME =ZONE 13
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 6.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.3	6.0	6.9
A	3.900	3.000	5.000
B	-1.020	-1.220	-.800

SEQ. # 14 LOC IN REG NO 4 ******** MAP ZONE NAME =ZONE 14
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 4.75

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	7.0	6.0	7.3
A	4.400	3.200	5.600
B	-1.200	-1.200	-1.000

SEQ. # 15 LOC IN REG NO 3 ******** MAP ZONE NAME =ZONE CZ15
OCCURRENCE MODEL IN MAGNITUDE LINEAR RANGE OF (A-B*M) MODEL IS 3.75 6.25

PARAMETER	BEST ESTIMATE	LOWER LIMIT	UPPER LIMIT
UP MAG CO	6.0	5.8	6.3
A	5.230	4.830	5.630
B	-1.210	-1.300	-1.110

*********** SEISMICITY DATA FOR EXPERT 13 **********

TABLE B13.3 (Cont.)

```
*****************************************************************************************************
SEQ. # 16     LOC IN REG NO  4                       ******** MAP ZONE NAME =ZONE CZ16
OCCURRENCE MODEL IN MAGNITUDE      LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75        5.50
PARAMETER                         BEST ESTIMATE                   LOWER LIMIT                  UPPER LIMIT
UP MAG CO                              5.2                            5.0                           5.6
    A                                  3.750                          3.301                         4.110
    B                                 -1.100                         -1.210                         -.990
*****************************************************************************************************
SEQ. # 17     LOC IN REG NO  2                       ******** MAP ZONE NAME =ZONE CZ17
OCCURRENCE MODEL IN MAGNITUDE      LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75        5.20
PARAMETER                         BEST ESTIMATE                   LOWER LIMIT                  UPPER LIMIT
UP MAG CO                              5.8                            5.0                           6.1
    A                                  4.174                          3.774                         4.574
    B                                 -1.150                         -1.250                        -1.050
*****************************************************************************************************
SEQ. # 18     LOC IN REG NO  0                       ******** MAP ZONE NAME =ZONE 18
OCCURRENCE MODEL IN MAGNITUDE      LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75        5.00
PARAMETER                         BEST ESTIMATE                   LOWER LIMIT                  UPPER LIMIT
UP MAG CO                              5.8                            5.6                           6.0
    A                                  1.950                          1.250                         2.650
    B                                  -.740                         -1.040                         -.540
*****************************************************************************************************
SEQ. # 19     LOC IN REG NO  0                       ******** MAP ZONE NAME =ZONE CZ18
OCCURRENCE MODEL IN MAGNITUDE      LINEAR RANGE OF       (A-B*M)   MODEL IS        3.75        4.70
PARAMETER                         BEST ESTIMATE                   LOWER LIMIT                  UPPER LIMIT
UP MAG CO                              5.7                            5.5                           5.9
    A                                  4.174                          3.774                         4.574
    B                                 -1.150                         -1.250                        -1.050
*****************************************************************************************************
SEQ. # 20     LOC IN REG NO  0                       ******** MAP ZONE NAME =ZONE  5 (REPEAT)
OCCURRENCE MODEL IN MAGNITUDE      LINEAR RANGE OF       (A-B*M)   MODEL IS        1.60        6.20
PARAMETER                         BEST ESTIMATE                   LOWER LIMIT                  UPPER LIMIT
UP MAG CO                              7.4                            7.0                           7.5
    A                                  3.270                          3.190                         3.350
    B                                  -.890                          -.930                         -.850
*****************************************************************************************************
                  ********* END OF SEISMICITY DATA FOR EXPERT 13    ZONES *****

    EXPERT'S RELATION BETWEEN I(MAX) & MB IS
    I(MAX)=  2.00*MB -3.50
```

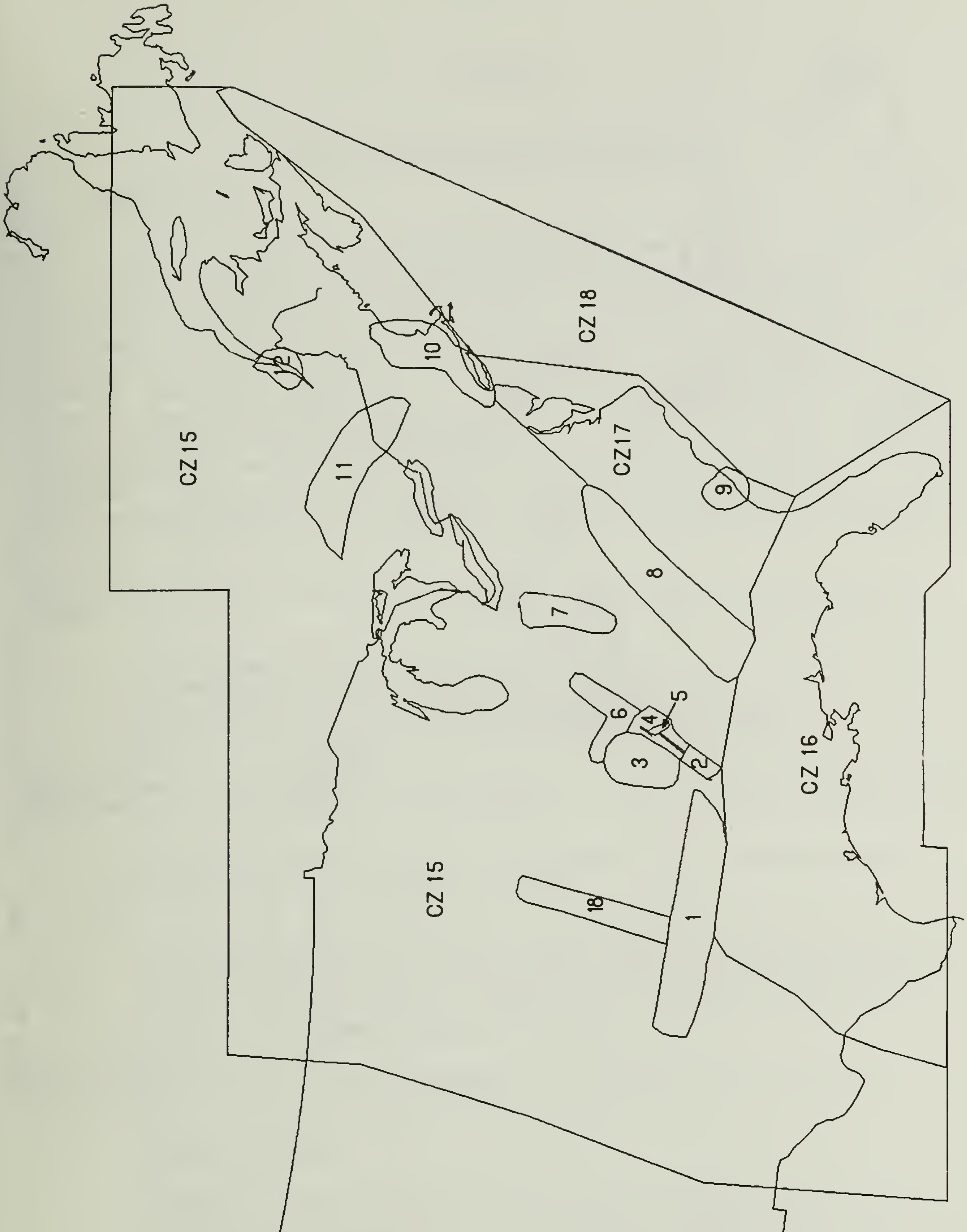

Figure B13.1 Seismic zonation base map for Expert 13.

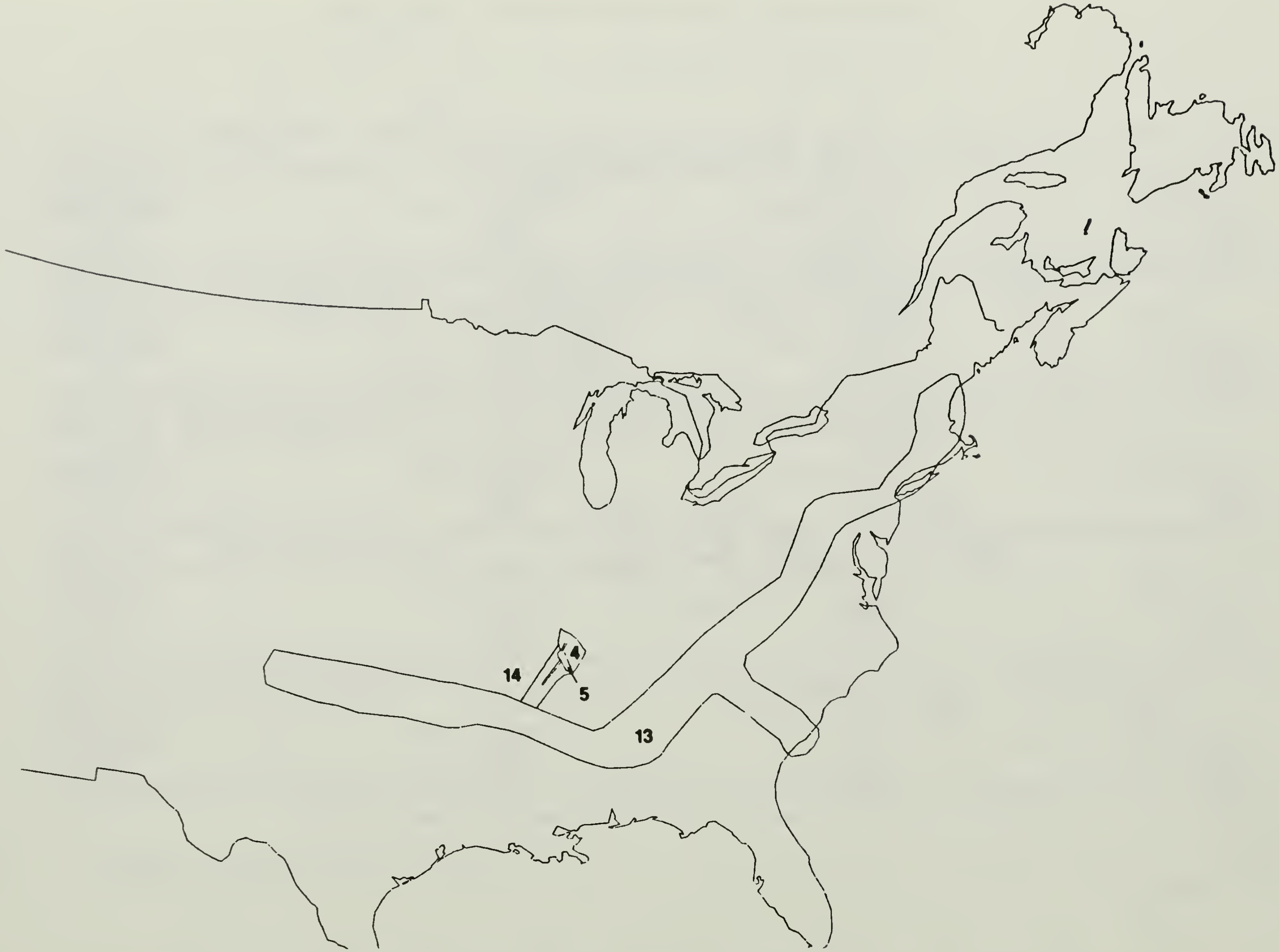

Figure B13.2 Map of alternative seismic zonations to Expert 13's base map.

APPENDIX C

Seismic Hazard Analysis Calculations

C.1 Introduction

Seismic hazard at a site is usually quantified through seismic hazard curves for the peak values of ground motion parameters, e.g. peak ground acceleration, at the site. The seismic hazard curve is a description of the probability during a given period of time, e.g., per year, that one or more earthquakes occur which result in the peak, over the duration of the earthquake, value of the ground motion parameter at the site exceeding the value a, given as a function of a. Figure C.1 illustrates a typical hazard curve for the peak ground acceleration (PGA) at a site shown on a logarithm scale, where the commonly used notation $A > a$ refers to the event that one or more earthquakes occur resulting in the PGA at the site exceeding a (cm/sec^2). It should be noted that the event $A > a$ is equivalent to the event that the maximum, over all earthquakes affecting the site, PGA is greater than a.

Evaluation of the seismic hazard curve at a site typically involves four steps:

- o Identification of seismic sources.
- o Specification of the seismicity for each source.
- o Specification of an attenuation/ground motion model.
- o Evaluation of the hazard curve or hazard spectrum.

For the Eastern United States (EUS) seismicity project steps 1 through 3 were implemented by the formation of two panels:

- o A panel of experts familiar with geological and seismological characteristics throughout the EUS.

- o A panel of experts familiar with the development of: (1) attenuation/ground motion models used to relate ground motion parameters at a site to characteristics of an earthquake at the source; and (2) methods for modeling the effects of local soil conditions on ground motion at the site.

Opinions about the appropriate parameters and models were elicited from members of the two panels in the following form:

- o Seismic Sources

  Seismic sources were identified by eliciting maps which partition the EUS into zones (area, line or point sources) representing regions of uniform seismicity in terms of occurrence rate and range and distribution of magnitude.

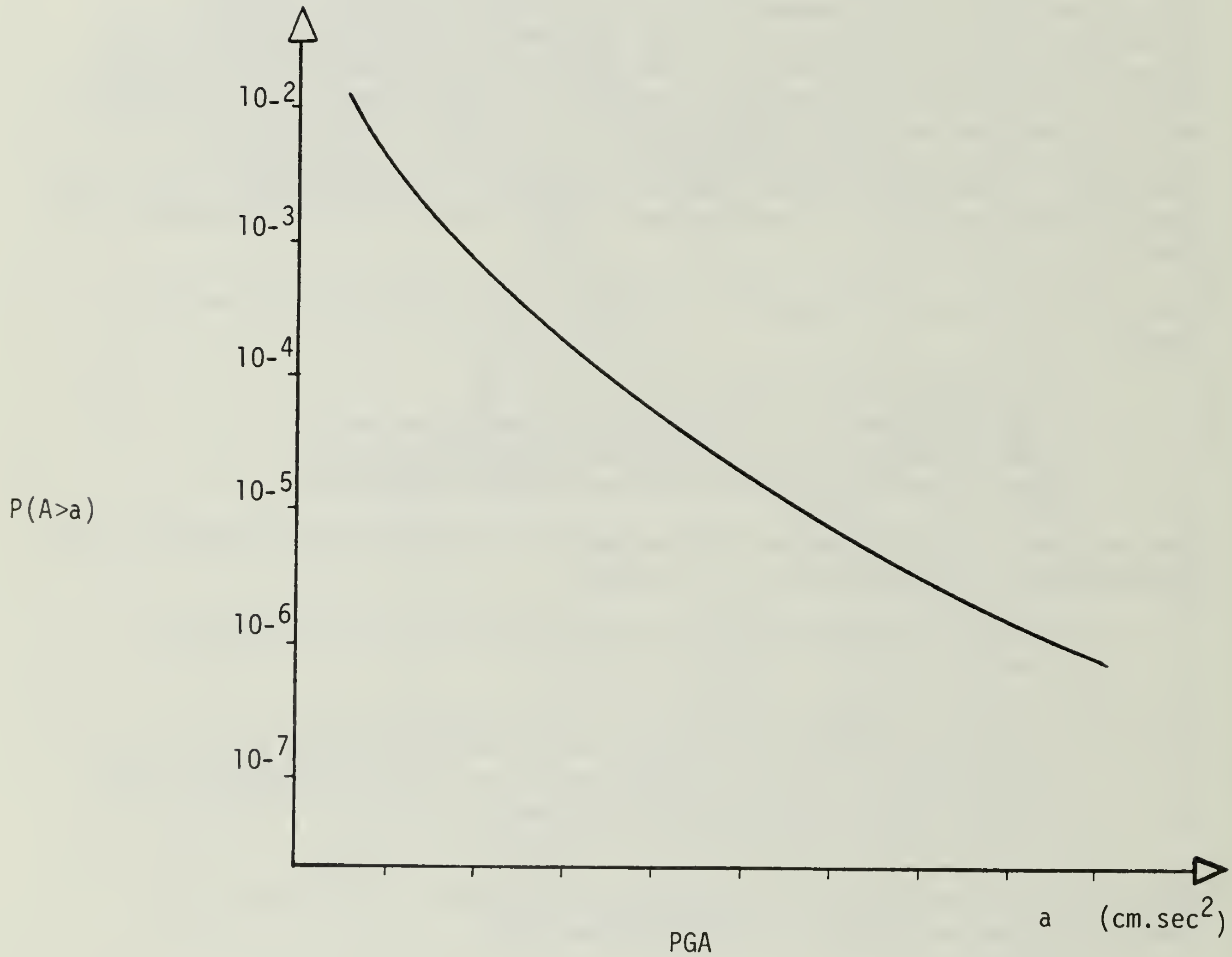

Fig. C.1. Typical seismic hazard curve.

- o **Seismicity**

  For each zone, seismicity information was elicited from the experts in terms of the:

  - Occurrence rate of earthquakes with magnitude above a minimum level, M_O = 3.75 M_{bLg} or IV MMI.

  - Upper magnitude cutoff, M_U, representing the largest magnitude expected to occur within a zone.

  - Distribution of magnitudes represented by a magnitude-recurrence relation.

- o **Attenuation/Ground Motion Model**

  Weights, representing the panelists' confidence in the applicability of a model, for a catalogue of attenuation/ground motion models were elicited.

- o **Local Site Effect**

  Weights, representing the panelists' confidence in the applicability of a method, for a collection of methods to adjust ground motion due to the effects of local site conditions were elicited.

Discussions about the elicitation, compilation and interpretation of the experts' opinions are given in other sections of this report. This appendix will concentrate on the methodology used to evaluate the seismic hazard curve (and spectra) at a site.

C.2 Philosophy of the Evaluation Methodology

Evaluation of the seismic hazard curve at a site is based on a probabilistic approach using the experts' opinions about seismicity and ground motion to specify models for the random events influencing the seismic hazard at a site. The method assumes that events, such as the occurrence of earthquakes within a zone, affecting ground motion at a site are subject to inherent physical variation and hence are properly treated as random events. Thus, the maximum value of a ground motion parameter experienced at a site over a period of time is a random quantity or variable. The hazard curve gives the probability of one or more earthquakes occurring resulting in the maximum value exceeding the value a. It is assumed to represent the likelihood, based on the inherent variation in the physical world, that the physical conditions will exist that lead to the maximum value of the ground motion parameter exceeding a. That is, the occurrence of an earthquake is assumed to be a random event and, if an earthquake does occur, the magnitude of the event and attenuation of ground motion from source to site are all subject to inherent variability. Thus, the ground motion at a site is variable and any ground motion parameter is properly considered a random variable. The seismic hazard curve is a description of the probability distribution of the maximum value of the ground motion parameter.

The probabilistic approach is based on modeling the physical variation by probability distributions and using these distributions to evaluate the probabilities of interest, i.e., the seismic hazard curve. However, characteristics of the distributions describing nature are unknown, thus the opinions of the experts are elicited to estimate these characteristics. Thus, the methodology produces an estimate of the seismic hazard curve which is based on the opinions provided by the experts on the two panels.

The evaluation method also recognizes that expert opinions about seismological properties and ground motion models are based on limited knowledge about the physical phenomena affecting these parameters, hence expert opinions are subject to uncertainty. The uncertainties associated with the experts' opinions do not contribute to the level of seismic hazard but do influence the effectiveness of the evaluation process in estimating the hazard. The experts' uncertainties are incorporated into the hazard analyses by developing a set of bounds for the hazard curve. The level of uncertainty is quantified by modeling the experts' uncertainties by probability distribution. A second source of uncertainty associated with a probabilistic analysis is the choice of probabilistic models used to model physical phenomena. These mathematical models are only approximations to the real world. The choice of models is a matter of judgement by the analyst and, like experts' opinions about seismicity and ground motion, are based on limited knowledge of the physical world. Uncertainties associated with the choice of mathematical models is more difficult to assess. Also, a comparison between different models can only be made if the evaluation of seismic hazard using competing models is actually done. This is not always possible. Thus, this type of uncertainty is not an integral part of the evaluation of hazard. However, sensitivity analyses have been conducted which describe the effect on the hazard estimates of some of the modeling assumptions.

The method for evaluating the seismic hazard curve at a site involves a two-stage estimation process:

- o A single hazard curve, referred to as the 'best estimate' hazard curve, is evaluated using the experts' best estimate evaluations of seismic sources, seismicity and attenuation/ground motion models.

- o The uncertainty in estimating the seismic hazard due to the uncertainties associated with the experts' opinions is quantified by evaluating bounds for the seismic hazard which reflect the experts' uncertainties. This analysis is called an 'uncertainty analysis'.

In addition to reflecting the uncertainty of a single pair (i.e., seismicity and attenuation experts) of experts, the uncertainty analysis, when the hazard estimates are combined over several experts, will also reflect the variation in opinions among experts. As part of the uncertainty analysis, in addition to the uncertainty bounds for the hazard curves, a "mean" hazard curve can also be produced. The arithmetic mean and geometric mean are options. These hazard curves are potential estimates of the hazard at a site if one wants to describe the hazard by a single curve. Thus, they are alternatives to the "best estimate" hazard curve. However, it must be realized that the "mean" hazard curve is not produced from a single set of seismic and ground motion parameters as is the best estimate curve. Rather, like the uncertainty bounds, it is the locus of points representing the mean value of P(A>a) at each value of a. The mean is taken with respect to the distribution of P(A>a) at each a due to the experts' uncertainty distributions.

Because the elicitation process involves several experts, at times it will be necessary to combine the information derived from several experts to evaluate a hazard curve which reflects the combined opinions of the several experts. The method developed for combining over experts is based on a self evaluation by the experts of their level of expertise with regard to seismological issues and attenuation/ground motion modeling respectively. For the seismicity panelists the self-evaluation was done for four regions, NE, SE, NC, SC, in the EUS. These four self weights were combined into a single weight which was used when combining over seismicity experts. The method of combining over experts, essentially a weighted average, assumes that the self weights reflect not only the experts' level of overall knowledge about seismological issues (or attenuation/ground motion modeling) but also reflects the experts' abilities to translate this knowledge into responses about characteristics of probability distributions. Thus, the method assumes that the self weights are a quantification of an individual's judgment of the utility of their opinions for estimating the seismic hazard. The weights for combining the self weights for the four regions are the probabilities that the largest value at the site of the ground motion parameter comes from each region. These probabilities, at the site, will vary for different sites.

Although self weights were used for the present analysis, the same methods could be used with weights derived from other sources such as weights from peers or weights developed by the analyst or any user of the methodology. The important criterion is that the weights should reflect some judgment of the utility of an experts' opinions for estimating the seismic hazard. That is, the weights should be a judgment of how well the estimated hazards, based on the experts' opinions, can be expected to describe the real seismic hazard.

C.3 Mathematical Background and Assumptions

C.3.1 Seismic Hazard Curve

Seismic hazard at a site is quantified by the values of a ground motion parameter, at the site, which is exceeded with a given probability in a specified number of years. The mathematical development of hazard relations will be based on peak ground acceleration (PGA) although identical relations hold for peak ground velocity (PGV) and spectral acceleration or velocity as well.

The parameter of interest is the probability that the PGA at the site will exceed a given value, a, at least once within the specified time period, t years. This probability, expressed as a function of a and denoted $P(A > a)$, is called the seismic hazard curve at the site. As noted earlier, the hazard curve is the tail of the complement of the cumulative distribution function for the random variable (i.e., the maximum PGA at the site, over all earthquakes affecting the site).

Typically, the region affecting ground motion at a site consists of a number of seismic source zones. The seismic hazard at the site is a combination of the hazard from all relevant sources. In addition, the value of the ground motion parameter, e.g. peak ground acceleration, will depend on both the distance of the source from the site as well as the magnitude of the earthquake at its source.

The following assumptions about the occurrence of earthquakes throughout the EUS form the basis for the probability calculations used to evaluate the hazard curve at a site:

- For each zone, it is assumed that earthquakes could occur randomly over time and uniformly at random within the zone.

- All earthquakes are assumed to be point sources, thus the fact that earthquakes are created by the rupture of tectonic faults of finite length is neglected.

- The occurrence of earthquakes is assumed to be independent between zones.

- The occurrence rate of earthquakes within a zone is considered to be constant; its value is based on the seismic and tectonic conditions that presently exist within the zone.

We further assume that:

- The expected number of earthquakes of magnitude m or greater, $\Lambda(m)$, occurring within a zone can be described by the magnitude-recurrence relation

  $$\log \Lambda(m) = H(m) \qquad M_O \leq m \leq M_U$$

  The functional form of H(m) is based on information elicited from the experts.

- Given the magnitude of an earthquake at its source and the distance of the site from the source, it is assumed that the physical variation in the PGA at the site is described by some probability distribution. For other than the Trifunac model of spectra (model #94 in Table B-1) the distribution was a lognormal distribution.

The hazard analysis is based on considering the effect above the minimum magnitude M_o. Under the assumption that earthquakes occur at random over time, the number $N_t(m)$ of earthquakes with magnitude greater than M, $m > M_o$, occurring within a zone in a time period of t years is a Poisson random variable with parameter $\Lambda(m)$. Thus, the probability of exactly n earthquakes with magnitudes greater than m in t years is

$$P[N_t(m)=n] = [t\Lambda(m)]^n \, e^{-t\Lambda(m)}/n! \qquad n=0,\ 1,\ldots \tag{C.1}$$

The occurrence rate $\Lambda(m)$ can be expressed as $\lambda_o P(M>m|M>Mo)$ where λ_o is the expected member of earthquakes of magnitude greater than the minimum M_o and $P(M>m|M>M_o)$ is the probability, given an earthquake, that the magnitude exceeds m conditional on the magnitude exceeding M_o. Two models for the occurrence rate $\Lambda(m)$ based on alternative views of the conditional distribution of magnitude given an earthquake were used. These are discussed in Sec. C.3.2.

Using the assumption that earthquakes are point sources which occur at random uniformly throughout a zone, if $N_t(r,m)$ is the number of earthquakes in t years of magnitude greater than m occurring at points in the zone which are r(km) to r+dr(km) from the site, then $N_t(r,m)$ is a Poisson random variable with parameter

$$\Lambda(m)\ f_R(r)dr \tag{C.2}$$

where $f_R(r)$ is the density function for the distribution of the distance from the site to the points within the zone and $\Lambda(m)$ now denotes the occurrence rate per unit area per year. The distribution $f_R(r)$ is the proportion of a given zone located within specific ranges of distance from the site (see Sec. 2).

Given an earthquake of magnitude greater than m at a distance (r,r+dr) from the site the ground motion parameter, e.g. PGA, at the site depends on the attenuation of the source energy between the source and the site. We assume this to be a random process. Specifically, we assume the PGA at the site is a lognormal random variable such that the mean of the logarithm of PGA is given by the attenuation/ground motion model which depends on m and r. This assumption was also made for spectra, except for Trifunac's model which is itself a distribution function. We denote the conditional probability of PGA exceeding the value a by $P(A > a|m,r)$.

Let $N_t(a)$ denote the random variable, the number of earthquakes occurring in a zone in t years such that the PGA at the site is greater than a. The probability that one or more earthquakes occur in t years resulting in the PGA at the site exceeding a, denoted $P(A_t > a)$, is given by

$$P(A_t > a) = P(N_t(a) \geq 1) \quad (C.3)$$

Considering the range of magnitudes (M_o, M_U), where M_U is the upper magnitude cutoff, and all distances r>0, $N_t(a)$ is a Poisson random variable with parameter ($\lambda_a t$), where

$$\lambda_a = \lambda_o \int_{M_o}^{M_U} \int_{r>o} P(A > a|m,r) f_R(r)dr \; dF_M(m|M_o,M_U) \quad (C.4)$$

and $F_M(m|M_o, M_U)$ denotes the distribution function of the distribution of magnitudes given an earthquake, conditional on minimum magnitude M_o and upper magnitude cutoff M_U.

In our analysis we approximated the integral numerically ty subdividing both the distance and magnitude range into subintervals. Distances out to 1250 km were considered and subdivided into 18 subintervals. Details of the partition are given in Section 2.3. Let $\Pi(r_k)$ denote the proportion of the zone at distances in the kth subinterval, i.e.

$$\Pi(r_k) = \int_{\substack{r \text{ in} \\ k\text{-th subinterval}}} f_R(r)dr \quad (C.5)$$

Similarly, magnitudes were partitioned into subintervals of length 0.25 (M_{blg}) or 0.5 (MMI). Let m_j, the midpoint of the jth magnitude subinterval, be the representative value for the jth subinterval, and let

$$\lambda(m_j) = \lambda_o \int_{m_j-\Delta}^{m_j+\Delta} dF_M(m|M_o,M_U) \quad (C.6)$$

$$= \Lambda(m_j - \Delta) - \Lambda(m_j + \Delta)$$

= the expected number of earthquakes per year per unit area with magnitudes in the jth subinterval ($m_j - \Delta$, $m_j + \Delta$)

Then, the parameter $\lambda_a t$ for the Poisson distribution of $N_t(a)$ is

$$\lambda_a t \doteq t \sum_{j=1}^{J} \lambda(m_j) \sum_{k=1}^{K} \pi(r_k) P(A > a|m_j,r_k) \quad (C.7)$$

Therefore, for a given source zone q, the probability that the maximum PGA at the site, in a time period of length t, due to earthquakes occurring in zone q exceeds a is

$$P_q(A_t > a) = P_q(N_t(a) \geq 1)$$

$$= 1 - \exp\left[-t \sum_{j=1}^{J} \lambda_q(m_j) \sum_{k=1}^{K} \Pi_q(r_k) P(A > a | m_j, r_k)\right] \quad (C.8)$$

where $\lambda_q(\cdot)$ and $\Pi_q(\cdot)$ are dependent on the zone.

Finally, under the assumption that events between zones are independent, the seismic hazard in t years at a site can be evaluated by

$$P(A_t > a) = 1 - \Pi_q\left[1 - P_q(A_t > a)\right]$$

$$= 1 - \Pi_q\left\{\exp\left[-t \sum_{j=1}^{J} \lambda_q(m_j) \sum_{k=1}^{K} \Pi_q(r_k) P(A > a | m_j, r_k)\right]\right\} \quad (C.9)$$

In the analysis the range of accelerations a is also discretized, thus the hazard is actually evaluated at a finite number (10) of accelerations, a_i, i=1, ... I=10.

C.3.2 Magnitude-Recurrence Models

The hazard at a site, as described by the hazard curve, depends on the occurrence rate $\Lambda(m)$ of earthquakes of magnitudes m or greater. The occurrence rate varies with m and depends on the occurrence rate Λ_o of earthquakes of magnitudes greater than the minimum M_o and the distribution of earthquake magnitudes $F_M(m|M_o, M_U)$. The dependence of $\Lambda(m)$, the occurrence rate or expected number of earthquakes per unit time per unit area, on m is called the magnitude-recurrence relationship. Two primary models for the magnitude-recurrence relationship were used in the hazard analysis for this project.

A common model for approximating the distribution of earthquake magnitudes, given an earthquake, is the exponential model. If Λ_o is the expected number of earthquakes of magnitudes M_o or greater and if $F_M(m|M_o)$, the distribution of magnitudes given an earthquake conditional on magnitude $M > M_o$, is exponential, the expected number of earthquakes of magnitude m or greater is

$$\Lambda(m) = \lambda_o e^{-\beta(m-M_o)} \qquad m>M_o \quad (C.10)$$

$$= \lambda_o e^{\beta M_o} e^{-\beta m}$$

or

$$\log_{10} \Lambda(m) = \log_{10}\lambda_o + \beta M_o \log_{10}e - \beta m \log_{10}e \quad (C.11)$$

which has the form

$$\log_{10}\Lambda(m) = a + b\,m \qquad (C.12)$$

with

$$b = -\beta < 0$$

$$a = \log_{10}\lambda_o - b\,M_o$$

This model assumes that magnitude can be arbitrarily large. Physically, this is not possible. Since the principle contributors to the hazard at a site are large magnitudes, the assumption of arbitrarily large magnitude is unacceptable. Thus, an upper magniltude cutoff, i.e. largest possible magnitude, is assumed. This was one of the parameters elicited from the seismicity panel.

To accomodate the limiting magnitude, some adjustment must be made in the magnitude-recurrence model in Equation C.11. Two adjustments were considered:

1. <u>LLNL Model</u>

   The basic philosophy in the LLNL model is that the linear model, Eq. (C.12),

$$\log_{10}\Lambda(m) = a + bm \qquad (C.13)$$

is applicable for some range (M_{LB}, M_{UB}) of magnitudes, subject to the two obvious restrictions

- $\Lambda(M_o) = \lambda_o$, i.e., $\log_{10}\Lambda(M_o) = \log_{10}\lambda_o$
- $\Lambda(M_U) = 0$, i.e., $\log_{10}\Lambda(M_U) = -\infty$

Under this philosophy the linear model in Eq. (C.13) must be adjusted to satisfy the restrictions in the intervals (M_o, M_{LB}) and (M_{UB}, M_U). An adjusted model is shown in Fig. C.2.

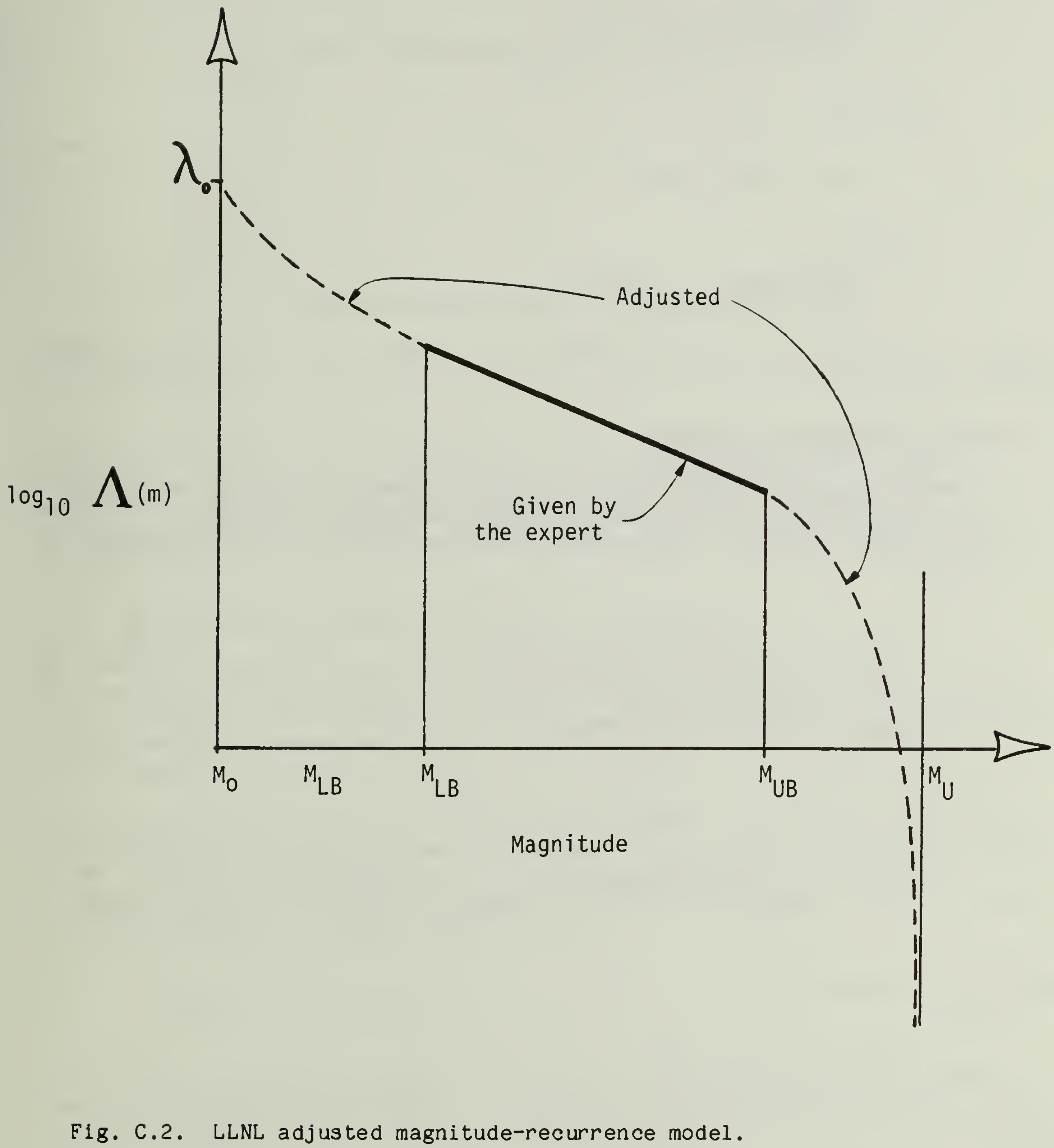

Fig. C.2. LLNL adjusted magnitude-recurrence model.

The adjustments to the exponential model, based on the LLNL philosophy, in the two regions are respectively;

- (M_o, M_{LB}): quadratic polynomial subject to
  - $\Lambda(M_o) = \lambda_o$
  - $\log_{10}\Lambda(M_{LB}) = a + b\ M_{LB}$
  - derivative of $\Lambda(m)$ is continuous at $m = M_{LB}$

- (M_{UB}, M_U): model

$$\Lambda(m) = \alpha e^{\beta m}\ (m - M_U)^2$$

subject to

  - $\log_{10}\Lambda(M_{UB}) = a + bM_{UB}$
  - derivative of $\Lambda(m)$ is continuous at $m = M_{UB}$

Further details on the use of the LLNL model in the hazard analysis are given in Section C.5.2.

2. Truncated Exponential Model

A second method for adjusting the exponential magnitude-recurrence model in Eq. C.12 is based on assuming the distribution of magnitudes, conditional on $M_o < m < M_U$, to be a truncated exponential distribution. That is,

$$P(M > m | M_o, M_U) = \frac{e^{-\beta(m-M_o)}\left[1 - e^{-\beta(M_U-m)}\right]}{\left[1 - e^{-\beta(M_U-M_o)}\right]} \qquad (C.14)$$

The adjusted magnitude-recurrence model is

$$\log_{10}\Lambda(m) = \log_{10}\lambda_o + \beta\ M_o\log_{10}e - \beta\ m\ \log_{10}e$$

$$+ \log_{10}\left[1 - e^{-\beta(M_U-m)}\right] - \log_{10}\left[1 - e^{-\beta(M_U-M_o)}\right] \qquad (C.15)$$

which is of the form

$$\log_{10}\ \Lambda\ (m) = a + bm + G(m) \qquad (C.16)$$

where

$$a = \log_{10} \lambda_o - \beta M_o \log_{10} e$$

$$b = -\beta \log_{10} e$$

$$G(m) = -\log_{10}[1 - e^{-\beta(M_U - M_o)}] + \log_{10}[1 - e^{-\beta(M_U - m)}]$$

such that

$$G(M_o) = 0$$

A plot of the truncated exponential model is shown in Fig. C.3.

Details of the use of this model in the hazard analysis is given in Sec. C.5.2.

Although the seismicity panelists were given the choice of any model for the magnitude-recurrence relationship, all but one expert chose the linear model. These experts were then asked to choose between the two alternative adjustments. One expert chose a piecewise linear model. In this case separate adjustments were made, if necessary, in the intervals (M_o, M_{LB}) and (M_{UB},M_U).

C.3.3 Uniform Hazard Spectrum

The notion of a uniform hazard spectrum (UHS) is discussed in detail in ([1], Section 5.0). However, we summarize some of the mathematical aspects relevant to the evaluation methodology. A uniform hazard spectrum is developed such that for each frequency the spectral amplitude has the same probability of being exceeded in t years.

Based on the method outlined in the previous section, the hazard curve, i.e. the probability that the maximum PGA per year (in t years) exceeds the value a or the probability of exceedence, is assessed independently for each frequency. Assuming that the occurrence of earthquakes is a Poisson process, for each frequency, f (assuming t = 1 year),

$$P(A_f > a) = 1 - e^{-\lambda_a} \qquad \text{(C.17)}$$

where λ_a is the expected number of events per year such that the peak spectral acceleration at the site exceeds a. Therefore, the time between events such that $A_f > a$, denoted $T(A_f > a)$, has expected value

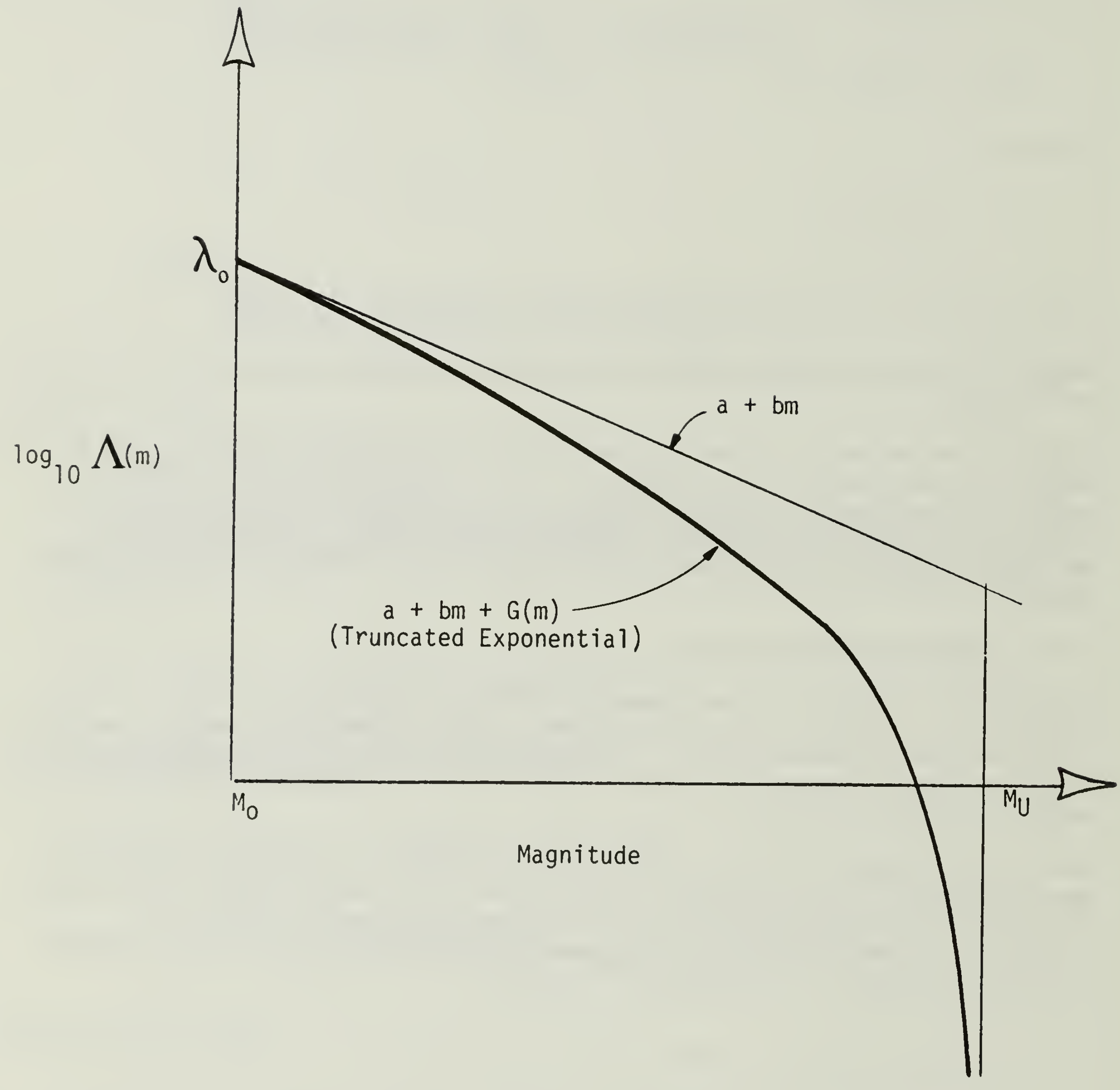

Fig. C.3. Truncated exponential magnitude-recurrence model.

$$RP_f(a) = \varepsilon[T(A_f > a)] = \lambda_a^{-1} \quad (C.18)$$

which is the return period of events such that $A_f > a$ at the site. Therefore the relation between the return period and the probability of exceedence is

$$RP_f(a) = \{-\ln[1 - P(A_f > a)]\}^{-1}$$

$$\doteq [P(A_f > a)]^{-1} \quad , \quad (C.19)$$

for long return periods.

A typical plot of the return period, on the log scale, versus a is shown in Fig. C.4 for two frequencies. For a return period of interest, e.g., 10,000 years, the spectral PGA's corresponding to the return period are used as the spectral amplitudes for the different frequencies f_1, f_2, ... (9 frequencies were included in the analysis).

C.3.4 Weights for Seismicity Experts

Both seismicity and attenuation/ground motion model information were elicited from several experts. Thus, seismic hazard curves could be estimated using information from any pair of experts--a seismic expert and a ground motion model expert. In addition, it may be appropriate to combine the opinions of the experts. This could be done at two points in the evaluation process

- A consensus could be reached on a single set (or a finite collection) of values for the seismicity parameters as well as agreement on the 'best' attenuation/ground motion model or set of models.
- The opinions of the individual experts, i.e. a seismic and ground motion expert pair, could be used to evaluate a seismic hazard curve and then the resulting hazard curves could be combined to form a combined hazard curve which represents, in some fashion, the opinions of all the experts.

We feel it is important to retain the diversity of opinions that might have existed between the experts, thus hazard curves were evaluated for every pair, i.e. seismicity-ground motion pair, of experts and these were subsequently combined to evaluate an 'average' hazard curve.

The method for combining the individual results is based on a weighted average of the individual hazard curves or uncertainty distributions. The weights for the attenuation model experts are the normalized values of the self-weights the experts provided. The weights for the seismicity experts are themselves a weighted average of the four regional self-weights provided by the experts.

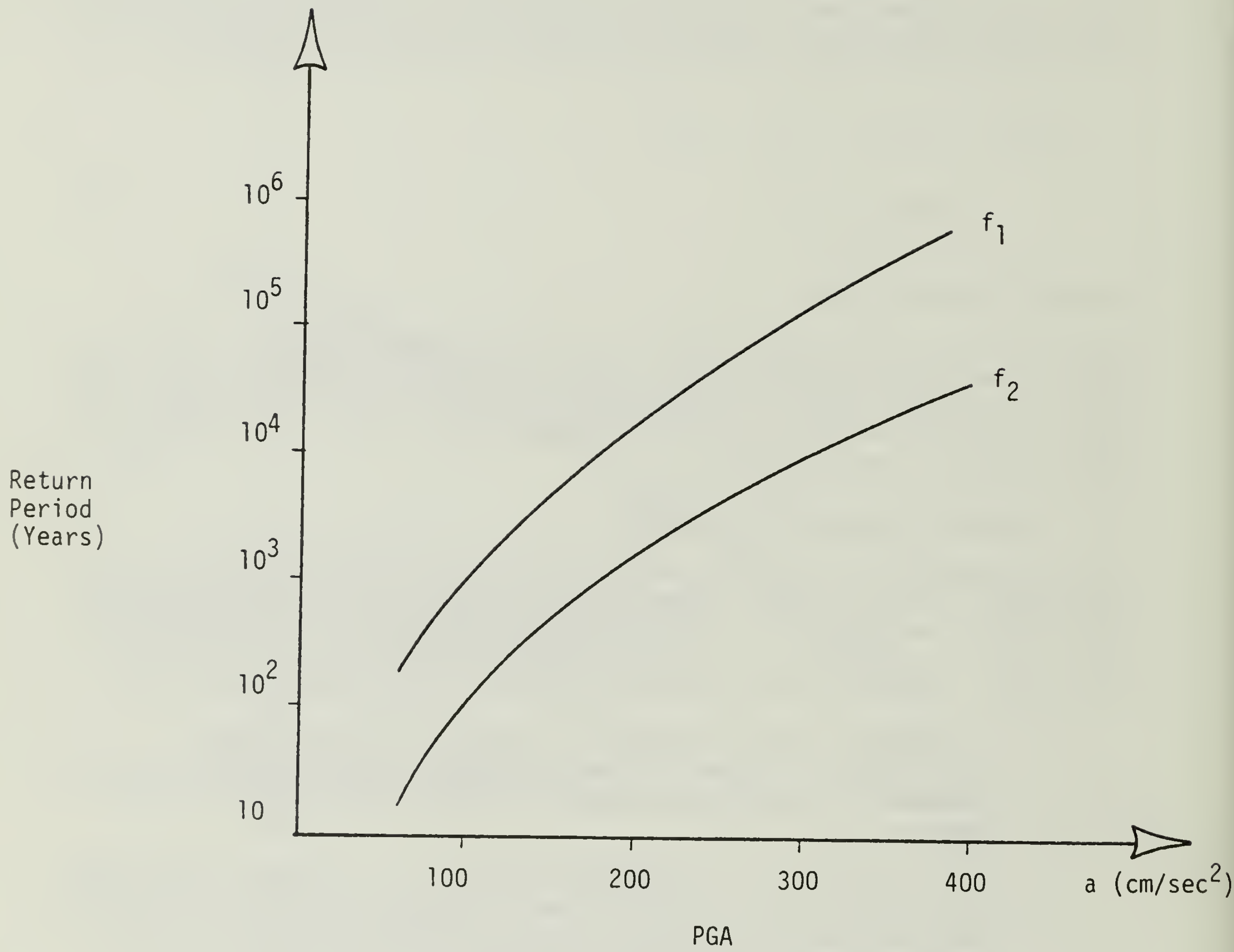

Fig. C.4. Relationship between spectral acceleration and return period.

Although the following development is not entirely consistent with the general philosophy of the overall evaluation process, it does provide a convenient basis for combining the regional self-weights for the seismicity experts into a single 'self-weight'.

Let s index the sth seismic expert, s=1, . . ., S and let w index the wth region of the EUS, w = 1, 2, 3, 4. Also let W_{sw} denote the self-weight of expert s in the wth region. Let

$$A_w = \max_{\substack{q \text{ in wth} \\ \text{region}}} (A_q;\ q = 1 \ldots N_w)$$

be the maximum PGA at the site due to earthquakes originating in the wth region. Based on the best estimate information from the sth expert, his assessment of the cumulative distribution function for A_w is

$$\Omega_{sw}(a) = \prod_{\substack{q \text{ in wth} \\ \text{region}}} \left[1 - \hat{P}_{sw}(A_q > a)\right] \qquad \text{(C.20)}$$

where $\hat{P}_{sw}(\cdot)$ is the estimated probability based on the best estimate of the seismic parameters provided by the sth expert.

One way of interpreting $\Omega_{sw}(\cdot)$ is to consider it to be the expert's assessment of the value of A_w, the maximum PGA at the site due to earthquakes in the wth region. In this context, one might also consider the expert's self weight W_{sw} as an expression of his utility for $\Omega_{sw}(\cdot)$ as a predictor of A_w.

For the hazard analysis the parameter of interest is

$$A = \max_{w} (A_w : w = 1, \ldots, 4)$$

the maximum PGA at the site. Given the assessment $\Omega_{sw}(\cdot)$ for A_w, the sth expert's assessment of A is

$$\Omega_s(a) = \prod_{w} \Omega_{sw}(a)$$

$$= \prod_{w} \prod_{\substack{q \text{ in wth} \\ \text{region}}} \{1 - \hat{P}_{sw}(A_q > a)\} \qquad \text{(C.21)}$$

Then, the expected utility for $\Omega_s(a)$ as a predictor of A is

$$W_s = \sum_{w} W_{sw} P(A = A_w) \qquad \text{(C.22)}$$

where $P(A = A_w)$ is the probability that the maximum PGA at the site results from an earthquake originating in the wth region. The normalized value of W_s is the weight assigned to the sth seismicity expert where $P(A = A_w)$ is estimated from the expert's best estimate $P_{sw}(A_t > a)$ of the distribution of the maximum PGA at a site due to earthquakes originating in the wth region.

The experts were not asked to give their opinions about the value of A nor were they asked about their utility for their opinions, thus, this development of W_s does not model precisely the elicitation conducted in this project. However, it does provide a rational method for combining the self weights in the 4 regions into a single weight for each seismicity expert. In addition, it does have some appealing features:

- weights vary between sites
- the weight will be "high" if the self weight is highest in the regions with the highest probability of producing the maximum PGA at the site.
- the weight will be "low" if the self weight is highest in the regions with the lowest probability of producing the maximum PGA at the site.

C.4 Summary of Elicitation Results - Inputs for the Evaluation Process

Detailed discussions of the elicitation, compilation and interpretation of the experts' opinions are presented in previous sections of the report. However, to provide continuity in the presentation of the probabilistic calculations it is necessary to summarize the elicited opinions as they are used as inputs into the estimation of the seismic hazard at a site.

C.4.1 Seismic Source Indentification

Each seismicity expert was asked to identify seismic sources throughout the EUS, expressed in terms of a complete zonation of the region. Identification of zones throughout the EUS was elicited in two forms:

- A 'best estimate' map, representing, in the expert's opinion, the most appropriate zonation of the EUS.
- Alternative zonations representing the expert's uncertainty about the zonation, produced by
    - expressing a 'level of confidence' or degree of belief that a zone should be identified as a source separate from the surrounding area

- suggesting alternative configurations for individual zones or clusters of zones along with a measure of degree of belief for each configuration.

Using the program module COMAP the collection of all possible maps along with the degree of belief (probability) for each map could be produced. Actually, a maximum of 30 maps, with the highest probabilities, were inputs into the analysis.

C.4.2 Seismicity Parameters

For each zone identified on the maps for a seismicity expert estimates of the following seismicity parameters and models were elicited

- the upper magnitude cutoff, M_U - largest magnitude expected to occur under current geologic and tectonic conditions

- the occurrence rate λ_o of earthquakes with magnitude greater than a minimum M_o($3.75 m_{blg}$ or IV MMI) - λ_o is the expected number of events per year with magnitude greater than M_o

- the magnitude recurrence model,

$$\log_{10} \Lambda(m) = H(m)$$

  which relates the expected number of events per year with magnitudes greater than m, $\Lambda(m)$, to the level m.

Information elicited about these parameters, used as inputs into the analyses, were

- Upper magnitude cutoff, M_U

  - Best estimate, $\hat{M}_U$

  - Bounds (M_{UL}, M_{UU}) which represent the expert's level of confidence in the resources he relied on to estimate M_U. The range M_{UL}, M_{UU} was treated as absolute bounds for M_U. Thus we assumed that M_U, in the opinion of the expert, will not exceed M_{UU}. Conversely, we assume it is the experts opinion that M_U will exceed M_{UL}.

- Occurrence rate, λ_o

  - Best estimate, $\hat{\lambda}_o$

  - Bounds (λ_{oL}, λ_{oU}) which represent the expert's 'confidence' in the resources used to estimate λ_o. We treated λ_{oL} as the value of which the expert is 97.5% confident, based on the available resources, is the lowest value of λ_o. Conversely, λ_{oU} is the value which the expert is 97.5% confident is the largest value of λ_o.

- <u>Magnitude (intensity) recurrence relation</u>

  - A mathematical model for the magnitude recurrence relation, H(m), i.e. for the relationship between the logarithm of the expected number of earthquakes with magnitude greater or equal to m and the magnitude m. All but one expert chose a linear model

$$H(m) = a + bm \qquad (C.23)$$

The exceptional model was a piecewise linear model

$$H(m) = \begin{cases} a_1 + b_1 m & (M_{LB1}, M_{UB1}) \\ \\ a_2 + b_2 m & (M_{LB2}, M_{UB2}) \end{cases}$$

  - The range of magnitudes (M_{LB}, M_{UB}), $M_o \le M_{LB} < M_{UB} \le M_U$, over which the model is applicable.

  - A choice between the two alternative adjustments, (1) LLNL or (2) Truncated exponential, to the linear model to accomodate a finite maximum earthquake magnitude.

  - Best estimates and bounds for each of the parameters, i.e., a's, b's, in the model. The bounds for the coefficients were interpreted in the same way as the bounds for λ_o.

  - A choice between 3 levels of correlation:
    - zero correlation, i.e. independence
    - 'moderate' negative correlation
    - 'perfect', i.e., -1.0, correlation

    between the estimates of the coefficients a, b (see Vol. 2, Questionnaire 5 for more details).

C.4.3 Attenuation/Ground Motion Models

Elicitation of opinions about attenuation/ground motion models was based on providing the experts with a catalogue of models for each of the ground motion parameters, PGA, peak ground velocity (PGV), and spectral acceleration and velocity. Seven classes of PGA and PGV models were identified, five of which were intensity based models and two classes which were empirically derived models relating the ground motion parameter directly to the source characteristics.

The experts were asked to express their opinions in the following form. For each of the four regions NE, SE, NC, SC and the two magnitude scales M_{bLg} and MMI,

- The 'best estimate' model - the attenuation/ground motion model which, in their opinion, best models the expected ground motion at a site in terms of the source parameters, e.g. m, r.

- A subset of up to seven (six for spectra) models with associated levels of confidence; these models represent their uncertainty in predicting the expected ground motion at a site given the source magnitude and the source-to-site distance.

Part of the hazard analysis is based on the assumption that, given an earthquake of magnitude m at a distance r(km) from the site, the ground motion parameter at the site is variable. We assumed that the variation is approximated by a truncated distribution due to ground motion saturation. For all but the Trifunac spectra model (Model #94 of Table B-1) the ground motion model describes the mean of the distribution as a function of m and r.

In addition, the following were elicited:

- The best estimate and bounds for the coefficient of variation (standard deviation of the logarithm of the ground motion parameter) except for the Trifunac model.

- A choice between 4 models of saturation (described in Vol. 2, Questionnaire 6).

  I: an absolute maximum acceleration, independent of m and r

  II: maximum acceleration as a function of m and r; described by a fixed number of standard deviations from the mean

  III: an envelope of I and II

  IV: no saturation

  The information elicited was best estimates of

  I: an absolute maximum acceleration, a_1

  II: number, n, of standard deviations

  III: both an a_1 and an n.

The uncertainty between the ground motion models was summarized by considering the collection of models, with the corresponding confidences (probabilities) analogous to the treatment of the zonation maps. The bounds for the coefficient of variation was interpreted in the same way as the bounds for the seismicity parameters.

C.4.4 Correction for Local Site Effects

Most of the ground motion models in the catalogue of models considered for the hazard analysis are based on data derived from sites with different types of soil, e.g. hard rock, shallow soil, deep soil. However, it is known that the local soil conditions can have a significant effect on the values of the ground motion parameters for a given earthquake magnitude and distance. Thus, it is appropriate to consider adjustments to the ground motion models to account for the local site effects. Two types of corrections, which are described in detail in Sec. 3 and Vol. 2 Questionnaire 6, were considered in the hazard analysis. Therefore, the experts were asked to choose between three methods for handling the effects of local site conditions:

- o no correction to the basic ground motion model
- o a simple correction, i.e. only two types of sites--rock, soil
- o a categorical correction, i.e., a more extensive catagorization of site soil types

C.5 Evaluation Methodology

C.5.1 Introduction

If the parameters of the probability models, e.g. expected values, $\Lambda(m)$, and coefficients of the attenuation models, were all known, evaluation of the seismic hazard curve is straightforward and would follow the mathematical methods outlined in Section C.3. However, these parameters are not known so they must be estimated. Values of these parameters were elicited from experts, thus estimation of the hazard curve at a site is based on subjective judgements. Because opinions can only be based on limited knowledge of the physical factors affecting seismicity and attenuation of ground motion, there are uncertainties associated with these opinions. Therefore, the methods used to estimate a hazard curve should recognize the uncertainties associated with the values of the parameters based on expert opinions. The uncertainties associated with subjective assessments of physical phenomena are recognized in the procedure used to estimate the hazard at a site. The procedure involves a two-step estimation process:

- o Evaluation of a 'best estimate' hazard curve, i.e., evaluation of a hazard curve based on the experts' best estimates of the model parameters, e.g., $\hat{M}_U$, $\hat{\lambda}_0$.
- o Evaluation of a set of curves derived from the uncertainty in $P(A_t > a)$, for each a, attributable to the uncertainties in the estimates of the model parameters, i.e., quantification of the 'confidence', i.e., degree of belief or level of knowledge, about the model parameters, expressed by the experts.

The evaluation process also recognizes that there is a potential difference in the level of expertise between the members of each of the panels. Thus, whenever estimates are combined over experts, the combined estimate is based on weighting the estimates of the individual experts.

A summary graphical description of the overall estimation process is given in Fig. C.5. Although the description is given in terms of estimating a hazard curve, comparable calculations are performed for spectral velocities which in turn are used to estimate the uniform hazard spectrum.

C.5.2 Best Estimate Calculations

The method for evaluating the "best estimate" hazard curve is a straightforward application of the equations in Section C.3. The best estimates, as provided by each expert, are used as the parameters of the models and distributions needed to estimate the hazard curve at a site.

The flow chart of the seismic hazard calculations in Fig. C.5 is followed in describing the best estimate analysis:

Inputs

- o Per seismicity expert, s
  - o Self weights for the four regions: W_{sw}: w = 1,2,3,4
  - o Best estimate map consisting of
    - Zone index, q
    - δ_{wq} - Identifier of regional location of qth zone
    - $\{\Pi_q(r_k);\ K = 1, \ldots K\}$ - distribution of distances from site of points in qth zone
    - Best estimate occurrence rate $\hat{\lambda}_{oq}$ for each zone
    - Best estimate of upper magnitude cutoff $\hat{M}_{Uq}$ for each zone
    - Best estimate model coefficients and range for magnitude-recurrence model, $(\hat{a}_q,\ \hat{b}_q;\ M_{LBq},\ M_{UBq})$
    - choice between LLNL and truncated exponential models for adjusting the magnitude recurrence model
  - o Per attenuation expert, u
    - Self weights, W_{Au}
    - "Best Estimate" attenuation model, $\hat{G}_u(m,\ r)$
    - Best estimate of random variation for ground motion parameter, $\hat{\sigma}_{Ru}$
    - Choice of model for ground motion saturation
    - Choice of method for correcting for local site effects

Calculation of Probability Parameters

- o Conditional probability of PGA given magnitude m and range r, $P(A > a|m,\ r)$--derived from a truncated lognormal distribution with

START

↓

IDENTIFY SEISMICITY EXPERT(s)

↓

CALL ALEAS

- o Read in inputs
- o Calculate necessary probability parameters
- o Evaluate best estimate (BE) hazard curve for each ground motion expert
- o Evaluate BE hazard curve combined over ground motion experts
- o Evaluate weight W_s for seismicity expert
- o Evaluate contribution γ_{sq} from qth zone
- o Do uncertainty analysis for each ground motion expert
- o Compute bounds for $P(A > a)$ for all a for each ground motion expert
- o Compute bounds for $P(A > a)$ combined over all ground motion experts

↓

OUTPUT RESULTS FOR sth SEISMICITY EXPERT

↓

CREATE FILE OF RESULTS FOR COMB

↓

ITERATE OVER
s = 1, . . . S

↓

CALL COMB

- o Read in inputs
- o Combine BE hazard curves over all experts
- o Compute bounds for $P(A > a)$ for all values of a combined over all experts

↓

OUTPUTS

- o Combined BE hazard curves
- o 15th, 50th and 85th percentile curves
- o Optional; mean hazard curve

Fig. C.5. Summary flow chart of the seismic hazard calculations.

parameters for all models other than Trifunac's model of spectra (Model #94 in Table B-1)

$$\mu_u(m, r) = \hat{G}_u(m, r)$$

$$s_u = \hat{\sigma}_{Ru}$$

o Expected number of events with magnitude $m_j (j = 1, \ldots J)$, $\lambda_{sq}(m_j)$

To assess $\lambda_{sq}(m_j)$ for all $j = 1, \ldots, J$ it is necessary to have the occurrence rate $\Lambda_{sq}(m)$ identified for all m in $(M_o, \hat{M}_{Uq})$ where $\hat{M}_{Uq}$ is the best estimate of the upper magnitude cutoff in the qth zone.

1. If LLNL model selected:

- If $M_{LBq} = M_o$, $M_{UBq} \geq \hat{M}_{Uq}$,

  then

  $$\hat{\Lambda}_{sq}(M_o) = 10^{(\hat{a}_q + \hat{b}_q M_o)}$$

  $$\hat{\lambda}(m_J) = \hat{\Lambda}_{sq}(m_J - \Delta) \text{ if } 10^{(\hat{a}_q + \hat{b}_q \hat{M}_{Uq})} \neq 0$$

  where Δ is one-half the width of a magnitude segment created in the discretization of the magnitude axis.

- If $M_o < M_{LBq}$ or $M_{UBq} < \hat{M}_{Uq}$

  for $M_o \leq m \leq M_{LBq}$, $\hat{\Lambda}_{sq}(m)$ is based on a quadratic polynomial model subject to

  $$\hat{\Lambda}_{sq}(M_o) = \hat{\lambda}_{oq}$$

  $$\hat{\Lambda}_{sq}(M_{LBq}) = 10^{(\hat{a}_q + \hat{b}_q M_{LBq})}$$

  the derivative of $\hat{\Lambda}_{sq}(m)$ is continuous at $m = M_{LBq}$

- for $M_{UBq} \leq m \leq \hat{M}_{Uq}$, $\hat{\Lambda}_{sq}(m)$ is based on the model

  $$\Lambda_{sq}(m) = \alpha e^{\beta m}(m - \hat{M}_{Uq})^2$$

subject to

$$\Lambda_{sq}(M_{UBq}) = 10^{(\hat{a}_q + \hat{b}_q \hat{M}_{UBq})}$$

the derivation of $\hat{\Lambda}_{sq}(m)$ is continuous at $m = M_{UBq}$

A graphical illustration of the adjusted occurence rate $\hat{\Lambda}(m)$, assuming a linear magnitude recurrence relation

$$\log_{10}\Lambda(m) = a + bm$$

is given in Fig. C.6.

2. If truncated exponential model selected:

- If $M_{LBq} = M_o$, for $M_o < m < \hat{M}_{Uq}$,

$$\log_{10}\hat{\Lambda}_{sq}(m) = a + bm - \log_{10}[1 - e^{-\beta(MUq - M_o}]$$

$$+ \log_{10}[1 - e^{-\beta(\hat{M}Uq - m)}]$$

where

$$\beta = -b(\log_{10}e)^{-1}$$

- If $M_o < M_{LB}$,

for $M_o \leq m \leq M_{LBq}$, $\hat{\Lambda}_{sq}(m)$ is based on a quadratic polynomial model subject to

$$\hat{\Lambda}_{sq}(M_o) = \hat{\lambda}_{oq}$$

$$\hat{\Lambda}_{sq}(M_{LB}) = 10^{\hat{a}_q + \hat{b}_q M_{LBq}}$$

the derivative of $\hat{\Lambda}_{sq}(m)$ is continuous at $m = M_{LB}$ for $M_{LBq} \leq m < M_{Uq}$

$$\log_{10}\hat{\Lambda}_{sq} = a + bm - \log_{10}[1 - e^{-\beta(\hat{M}_{Uq} - M_{LBq})}]$$

$$+ \log_{10}[1 - e^{-\beta(\hat{M}_{Uq} - m)}]$$

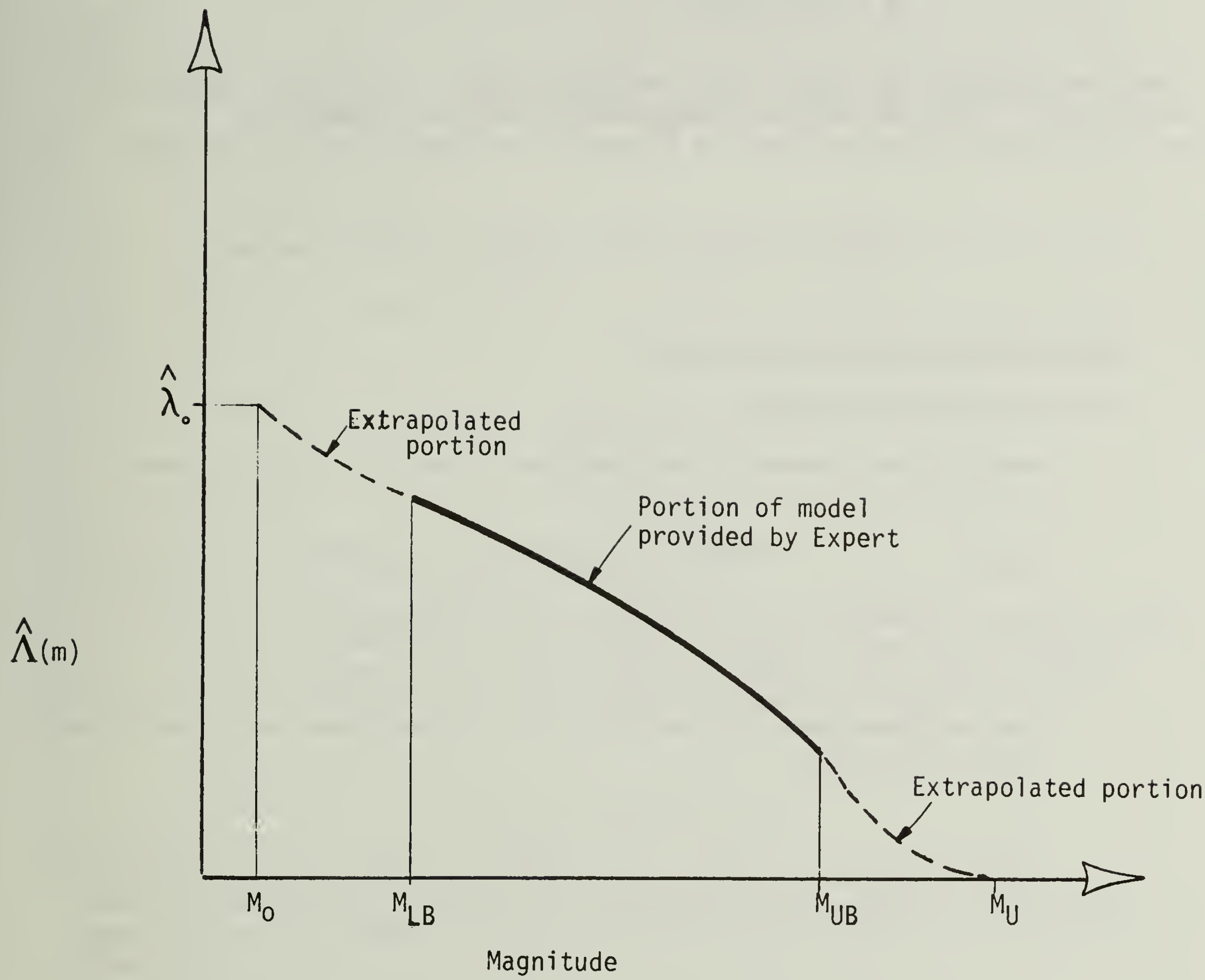

Fig. C.6. Adjustment of the magnitude-recurrence relation.

where

$$\beta = -b(\log_{10} e)^{-1}$$

Given the adjusted occurrence rate function $\hat{\Lambda}_{sq}(m)$, the expected number of earthquakes in the qth zone with magnitude in the jth segment $(m_j - \Delta, m_j + \Delta)$, based on the sth expert's seismicity parameters for the qth zone, is

$$\hat{\lambda}_{sq}(m_j) = \hat{\Lambda}_{sq}(m_j - \Delta) - \hat{\Lambda}_{sq}(m_j + \Delta)$$

<u>Best Estimate Hazard Calculations</u>

For each seismicity expert, s

- Best estimate hazard at the site due to events in the qth zone

$$\hat{P}_{suq}(A_t > a) = 1 - \exp\{-t \sum_{j=1}^{J} \hat{\lambda}_{sq}(m_j) \sum_{k=1}^{K} \pi_{sq}(r_k)\, \hat{P}_u(A > a \mid m_j, r_k)\}$$

for $a = a_1, a_2, \ldots, a_I$

- Best estimate hazard at the site due to events over all zones in the best estimate map

$$\hat{P}_{su}(A_t > a) = 1 - \prod_q \exp\{-t \sum_{j=1}^{J} \hat{\lambda}_{sq}(m_j) \sum_{k=1}^{K} \pi_{sq}(r_k)\, \hat{P}_u(A > a \mid m_j, r_k)\}$$

for $a = a_1, a_2, \ldots, a_I$

- Best estimate hazard at the site due to events in the qth zone, combined over ground motion experts

$$\hat{P}_{sq}(A_t > a) = \{ \sum_u W_{Au} \hat{P}_{suq}(A_t > a)\} / \sum_u W_{Au}$$

- Best estimate hazard at the site due to events over all zones in the best estimate map, combined over ground motion experts

$$\hat{P}_s(A_t > a) = \{ \sum_u W_{Au} \hat{P}_{su}(A_t > a)\} / \sum_u W_{Au}$$

We have used the terminology "best estimate" to identify these hazard curves. In reality these curves are the hazard curves at a site based on specific values, the experts' best estimates, for the inputs. Given the uncertainties associated with the inputs the best estimate hazard curve is unlikely to coincide with some estimate of the hazard curve in the classical statistical sense, such as mean, median, mode, or maximum likelihood.

Other Calculations

- Two other calculations, in addition to the best estimate hazard curves, are:
  - Per cent of hazard at a site attributable to the qth zone

$$\gamma_{sq}(a) = \frac{\hat{P}_{sq}(A_t > a)}{\hat{P}_s(A_t > a)}$$

  - Weight for sth seismicity expert

    A discussion of the background for evaluating a single weight for each seismicity expert is given in Section C.3.4. The weight for the sth seismicity expert, W_s, is the weighted average of the self weights in the four regions, i.e.

$$W_s = \sum_{w=1}^{4} W_{sw} \hat{P}_s(A = A_w)$$

where $\hat{P}_s(A = A_w)$ is the estimate, based on the sth expert's best estimate inputs, of the probability that the maximum PGA at the site is due to an earthquake originating in a zone in the wth region, which is the normalized value of

$$\hat{P}_s(A = A_w) = \{ \sum_{a_i} [\prod_{w' \neq w} \hat{P}_s(A_{w'} \le a_i)][\hat{P}_s(A_w \le a_{i+1}) - \hat{P}_s(A_w \le a_i)]\} / \hat{P}_s(A > a_1)$$

where

$$\hat{P}_s(A_w \le a_{I+1}) = 1$$

for all w, and

$$\hat{P}_s(A_w \le a) = \prod_q [\hat{P}_{sq}(A \le a)]^{\delta_{wq}}, \; a = a_1, \ldots, a_I; \; w = 1, \ldots, 4$$

$$\delta_{wq} = \begin{cases} 1 & \text{if the qth zone is in the wth region} \\ 0 & \text{otherwise} \end{cases}$$

Note that $P_s(A_w \le a)$ is the probability that the maximum PGA at the site due to earthquakes from the wth region is no greater than a.

Although the best estimate calculations have been presented in terms of the PGA, analogous calculations are applicable for the PGV and spectral accelerations or velocities. If a uniform hazard spectrum is the desired output, a best estimate hazard or probability of exceedance curve is evaluated for several (9) frequencies or periods. Then the spectral amplitude for the uniform hazard spectrum is evaluated as follows:

- o For return period RP, let a_i be the acceleration such that for frequency f,

  $$\ln P(A_f > a_i) > \ln RP^{-1} > \ln P(A_f > a_{i+1})$$

  Based on a linear interpolation of the probability of exceedance curve, the spectral amplitude at f is

$$a_{RP}(f) = \exp\left\{\ln a_i - \frac{\ln\left(\frac{a_i}{a_{i+1}}\right)}{\left[\ln \frac{P(A_f > a_i)}{P(A_f > a_{i+1})}\right]} \ln\left[\frac{P(A_f > a_i)}{(RP)^{-1}}\right]\right\}$$

If $\ln RP^{-1} > \ln P(A_f > a_I)$, the spectral amplitude at f is evaluated by a quadratic extrapolation of $\ln P(A_f > a)$.

Finally, after the best estimate calculations are completed for all seismicity experts, the best estimate curves are combined over all seismicity experts to produce the combined best estimate hazard curve. Following the philosophy that the weights are a measure of the level of expertise of the experts, the combined best estimate hazard curve is

$$\hat{P}(A_t > a) = \left\{\sum_s W_s \hat{P}_s(A_t > a)\right\} / \sum_s W_s$$

$$= \left\{\sum_s \sum_u W_s W_{Au} \hat{P}_{su}(A_t > a)\right\} / \sum_s \sum_u W_s W_{Au}$$

C.5.3 Uncertainty Analysis

In addition to their best estimate of the parameters used to evaluate the seismic hazard at a site, the experts also provided a measure of their confidence in the data, available information, and any other resources used to formulate their opinions. Quantification of confidence in the basis for the experts' opinions took several forms depending on the parameter:

- Uncertainty in identifying seismic sources (zones)

  A collection of alternative maps with associated "confidence" or degree of belief reflecting

  - Confidence that a zone is seismically distinct from the surrounding region.

  - Confidence in alternative boundary shapes for a zone or cluster of zones.

  The collection of maps for each seismicity expert was treated as a finite population, the probability associated with each map being the confidence assigned it by the expert.

- Uncertainty in seismicity parameters

  - For the occurrence rate λ_o, the bounds were treated as the 2.5th and 97.5th percentiles of a triangular distribution with mode equal to the best estimate of the parameter.

  - For the upper magnitude cutoff, the bounds were treated as the range of a triangular distribution with mode equal to the best estimate $\hat{M}_U$.

  - For the coefficients in the magnitude recurrence model, three models for the estimates (a, b) of the coefficients were considered:

    1. (a, b) are independent

    2. (a, b) are 'moderately' negatively correlated

    3. (a, b) are perfectly negatively correlated

    For 1. and 2. the bounds were treated as the 2.5th and 97.5th percentiles of a triangular distribution and the mode of the distribution of a is equal to the best estimate $\hat{a}$. In

1. the mode of the distribution of b is the best estimate $\hat{b}$

2. the distribution of b is conditional on a; specifically if $a = a_o$, the mode of the distribution of b, given $a = a_o$, is

$$\hat{b}_{a_o} = \frac{\hat{a} + \hat{b}M_{UB} - a_o}{M_{UB}}$$

under the restrictions that

$$\hat{b}_{ao} = \begin{cases} b_L \text{ (the lower bound for b), if } \hat{b}_{a_o} < b_L \\ b_U \text{ (the upper bound for b), if } \hat{b}_{a_o} > b_U \end{cases}$$

For 3. the bounds for a were treated as the 2.5th and 97.5th percentiles of a triangular distribution with mode a; the distribution of b, given a, is degenerate, i.e., if $a = a_o$,

$$b_{a_o} = - \frac{(a_o - a_L) - b_U m^*}{m^*}$$

where b_U is the upper bound for b, a_L is the lower bound for a, and

$$m^* = \frac{a_U - a_L}{b_U - b_L}$$

- o Uncertainty in attenuation models

  As for the zonation maps, the collection of attenuation models with their associated confidences (probabilities) were treated as a discrete probability distribution.

- o Uncertainty in random variation in PGA

  The uncertainty in σ_R was treated the same as λ_o.

The purpose of the uncertainty analysis is to produce a set of curves which reflect the variability in estimates of hazard at a site due to the uncertainties associated with the experts' opinions. The curves so produced describe the possible range of hazard, i.e., the range of values of P(A > a) for each a, at the site along with a measure of the experts' "confidence" in the values within the range. That is, for each pair of experts (seismicity-ground motion pair) it quantifies the variation in the estimates of hazard due to the uncertainties in the opinions of the individual experts. When combined over several experts, the variation in the hazard also reflects the variation in opinions about the input parameters between experts.

Propagation of the uncertainties in the inputs through the evaluation process is based on simulation methods. That is, each input parameter is treated as a random variable with the appropriate continuous or discrete probability distribution, e.g., λ_0 is treated as a triangular random variable and the maps and ground motion models have discrete distributions.

For each pair of experts (seismicity-ground motion pair) a random sample of each of the parameters, maps and ground motion models is selected from the appropriate distributions. Then,

- o Given a set of inputs, the hazard, $P_{su}(A_t > a|\text{inputs})$, $a = a_1, \ldots a_I$, is evaluated based on the inputs.

- o The sample $P_{su\ell}(A_t > a)$, $\ell = 1, \ldots L$ represents a sample from the "uncertainty" distribution for $P(A_t > a)$ for each $a = a_1, \ldots a_I$.

- o For each a_i, the empirical cumulative distribution function (CDF) is used to estimate the distribution for $P(A_t > a_i)$. This is illustrated in Fig. C.7. An approximation to the continuous CDF is also included in the illustration. $Q_{su}(\cdot)$ is an estimate of the uncertainty CDF for $P(A > a_i)$ given the uncertainties expressed by the (s, u)th pair of experts.

- o Using the percentiles, e.g., 15th, 50th, 85th, from $Q_{su}(\cdot)$ for each a_i, $i = 1, \ldots I$, a series of curves, reflecting the variation in hazard due to the uncertainties expressed by the (s, u)th pair of experts, can be produced.

- o Optional 'point' estimates of the hazard curve are based on

  - the arithmetic mean estimate, for each a

$$P^*_{su}(A_t > a) = \{\sum_{\ell=1}^{L} P_{su\ell}(A_t > a)\}/L$$

  - the geometric mean estimate, for each a,

$$P^{**}_{su}(A_t > a) = \{\prod_{\ell=1}^{L} P_{su\ell}(A_t > a)\}^{1/L}$$

To combine the uncertainty results over several experts, we estimate the uncertainty CDF for $P(A > a)$ which reflects the uncertainties of individual experts as well as the variation in opinions between experts. $Q_{su}(\cdot)$ is an estimate of this CDF if there were only the two experts. Using the weights W_{Au}, W_s as a measure of the level of expertise of the experts, the uncertainty

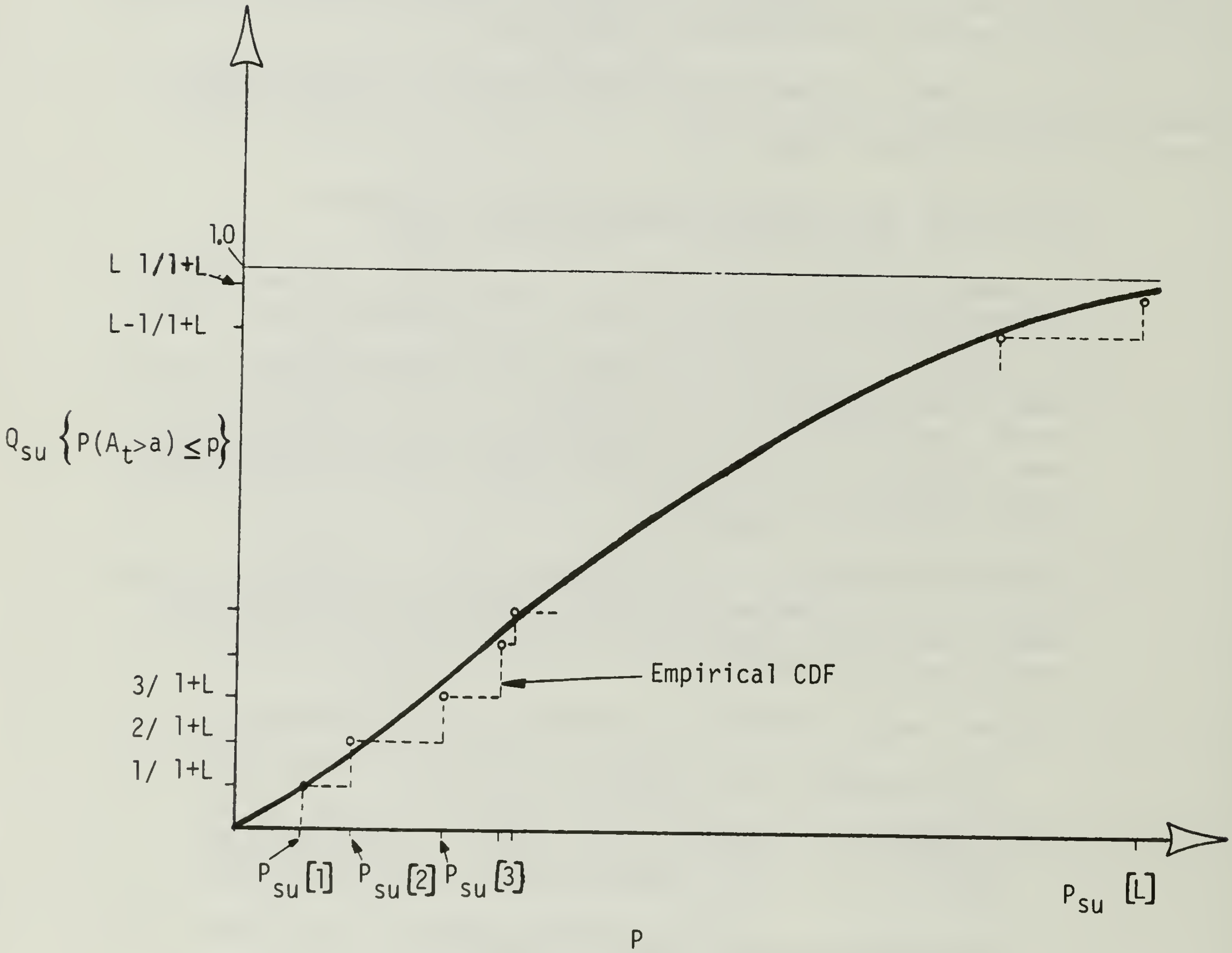

Fig. C.7. Illustration of the empirical CDF for $P(A_t > a)$.

CDF for $P(A > a)$ is estimated by taking a weighted average of the $Q_{su}(\cdot)$'s. That is, for each p

$$Q\{P(A > a) \leq p\} = [\sum_s \sum_u W_s W_{Au} Q_{su}\{P(A > a) \leq p\}]/\sum_s \sum_u W_s W_{Au}$$

This is illustrated in Fig. C.8 for three pairs of experts.

For each value a individually, the $Q_{su}(\cdot)$ for that value a is an estimate of the uncertainty associated with estimating $P(A > a)$. The combined CDF, $Q(\cdot)$ reflects a level of uncertainty consistent with the weights associated with the experts.

The combined CDF's for $P(A > a)$, for $a = a_1, \ldots, a_I$, are used to determine bounds for $P(A > a)$ for each a_i. For example, the 15th percentile $p_{.15}(a)$ is the value of p such that

$$Q\{P(A > a) \leq p\} = 0.15$$

Similarly for the 85th percentile.

The 15th and 85th curves, which reflect the potential variation in the hazard curve at a site, are the loci of the points $p_{.15}(a_i)$ and $p_{.85}(a_i)$, $i = 1, \ldots I$.

One must be careful in interpreting the bounds as hazard curves which correspond to a specific set of input parameters. The bounds are analogous to the bounds which are used to define Uniform Hazard Spectra (UHS). The UHS is the locus of points each corresponding to the same probability of exceedance and does not represent a distinct spectrum since the inherent physical correlation between the values at different frequencies has been lost in the calculations. However, it can be interpreted as an envelope of all possible spectra. Similarly the 85th and 15th percentile hazard curves do not represent the hazard curve corresponding to a specific set of input parameters. Rather they are the loci of probabilities such that the "Probability" (due to the uncertainty of the experts in their inputs) that $P(A > a)$ is less than the bound is .15 (.85) respectively for each a. It can be interpreted as an envelope of all possible hazard curves. It is not correct to interpret the 85th percentile curve as a hazard curve which will not be exceeded by 85 percent of the hazard curves produced by the uncertain parameters. It is true, however, that for a fixed value a the value $P_{.85}(A > a)$, taken from the 85th percentile curve at a, is an estimate of the value of $P(A > a)$ which has "degree of belief" or "confidence" 0.85 that it will not be exceeded, where the "confidence" is a weighted average of the levels of confidence of the individual experts.

To combine the optional point estimates of the hazard over all experts, the appropriate weights are applied. Specifically,

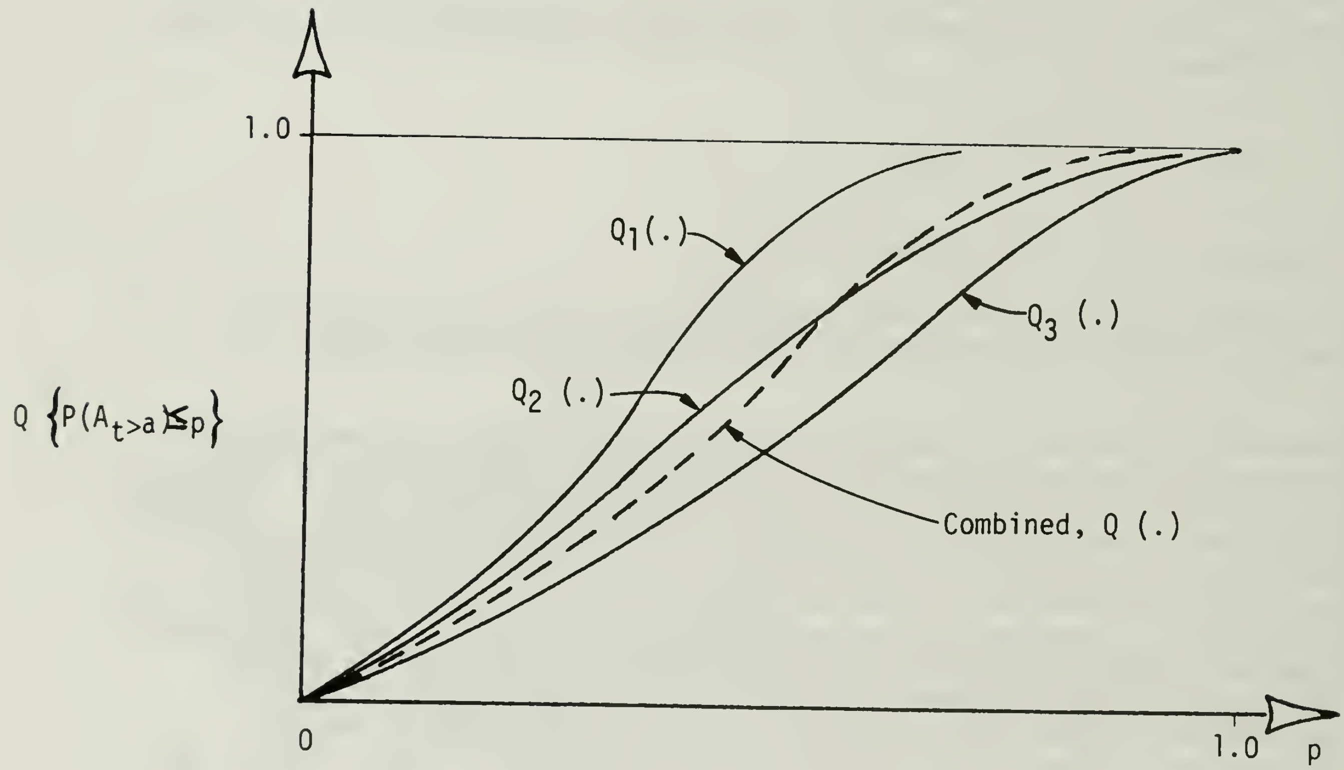

Fig. C.8. Illustration of uncertainty distribution for P(A > a) for fixed a.

- The arithmetic mean estimate, for each a,

$$P^{*}(A_t > a) = \left\{ \sum_s \sum_u \sum_{\ell=1}^{L} W_s W_{Au} P_{su\ell}(A_t > a) \right\} / L \sum_s \sum_u W_s W_{Au}$$

- The geometric mean estimate, for each a,

$$P^{**}(A_t > a) = \left\{ \prod_s \prod_u \left[\prod_{\ell=1}^{L} P_{su\ell}(A_t > a) \right]^{W_s W_{Au}} \right\}^{1/L \sum_s \sum_u W_s W_{Au}}$$

The estimated hazard curves are an envelope of the individual estimates over all accelerations.

C.6 PRACTICAL ASPECTS OF THE METHODOLOGY

C.6.1 Seismic Zonation, Complementary Zone and Probability of Distances

The difficulty of associating the location of most historical earthquakes which have occurred in the EUS with some known geotectonic formations has led to several basic simplifying assumptions common to most hazard analyses in modeling the seismicity of the EUS. First, it was assumed that, given a zone provided by a zonation expert, earthquakes could occur uniformly anywhere within this zone. Second, all earthquakes were assumed to be point sources, neglecting the fact that earthquakes are created by the rupture of tectonic faults of finite length. Thus, the only geometric input necessary for the hazard calculations is the distribution of the distances described by the density function $f_R(r)$ of the distance from the site to any point pertaining to the seismic source zone.

This probability distribution is the proportion of a given zone located within specific ranges of distances to the site. In the following, this distribution of distances will be referred to as the Probability of Distances and will be abbreviated by PRD. The program module which was specifically developed for the purpose of calculating the PRDs was appropriately named PRD.

The calculation of PRD for a zone, given a site, is straightforward, as is illustrated in Fig. C9. The proportion Π_{ij} of zone i bounded by distances R_{j-1} and R_j from the site is:

$$\Pi_{ij} = \frac{A_{ij}}{\text{(total area of zone i)}} \qquad \text{(C.24)}$$

where A_{ij} is the portion of the points of zone i at a distance r such that

$$R_{j-1} < r \leq R_j.$$

In the process of developing the program PRD, several practical aspects led to decisions of some importance for the calculated hazard at the site. These are related to the following:

(a) The format of the input zonation maps.
(b) The discrete nature of the calculations and the necessity of keeping the computer time for the overall analysis within reasonable bounds.

With respect to (a), the seismic zones provided by the experts had highly irregular shapes and a wide spectrum of sizes. Furthermore, most experts provided some alternatives to their best estimate zonations and in some cases there was no overall zone to model the remaining part of the EUS not specifically zoned.

The former aspect precluded the use of an analytical solution for performing the calculation in Eq. C24 and led to a discrete solution where a zone was discretized into small quadrangles. The latter two points were resolved by creating an ad hoc zone indexing system, allowing an easy treatment of zones within zones, and an overall complementary zone (CZ) covering the entire area of interest was created when not provided by the expert. This complementary zone was meant to include all parts of the EUS not specifically zoned by the expert. Strictly speaking, if an expert thought that he had included all potential seismic areas into specific zones, then the seismicity of the CZ should be zero. However, it was clear in our individual feedback discussions with the experts that a lack of specific zonation in some areas of the EUS might reflect more a lack of knowledge rather than the conviction that these areas were aseismic. Therefore, in some cases the CZ may have a non-zero seismicity. This is a very important point in light of the fact that some sites are located within the CZ for some seismicity expert's zonations. For these sites the hazard is primarily governed by the seismicity of the CZ.

(b) In order to get good resolution, the size of the quadrangles mentioned above must be as small as possible, especially when computing the PRD for the portions of zone close to the site or at the location of the site. On the other hand, it is necessary to keep the dimensions of these quadrangles as large as possible to avoid prohibitive computer time.

From experience, it is known that there exists a distance, relative to the site, beyond which the effects of earthquake occurrences is negligible. We call this distance the distance of influence an characterize it by the radius of the circle of influence. Furthermore, the resolution in the calculations of the PRD was made a function of the distance from the site. The size of the quadrangle was made equal to a 1 km square up to a distance of 24 km from the site, 3 km square from 24 km to 900 km, and 20 km square from 900 km to 1250 km. The zones entirely beyond 1250 km were not considered. These values were based on careful examination of sensitivity analyses where the minimum quadrangle size was as low as .1 km for the close-in zones and as large as 100 km in the remote zones. The close-in switch distance of 24 km was chosen after varying it from 5 km to 50 km.

The output of the program module PRD consists of a set of arrays of PRD's, one array for each seismic zone, for each alternative zone, and for the complementary zone if necessary. The content of each array is the set of proportions of the zone within each of the distances from the site. For reason of cost, the number of these intervals was also kept to the minimum possible. The intervals start small and increase in a roughly exponential fashion. After considering several sets of intervals, the following intervals were retained for the final calculations (in km):

5,5,5,10,10,15,25,25,25,25,50,50,50,100,100,200,200,350

Thus the outer limits of the distances(values of the R_j of Fig. C.9) are:

5,10,15,25,35,50,75,100,125,150,200,250,300,400,500,700,900,1250 km, and the actual distance array used in the hazard calculations is the array of mid-points:

2.5,7.5,12.5,20,30,42.5,62.5,87.5,112.5,137.5,175,225,275,350,450, 600,800 and 1075 km

C.6.2 Set of Alternative Maps

Each expert was given the opportunity to provide a best estimate map (BEM) and a set of alternatives to express his uncertainty in developing the zonation of the EUS. (For a more detailed discussion on the process of elicitation of responses from the experts, see Appendix B.)

The experts' uncertainty associated with zonation was expressed by the following:

a. Their level of confidence in the existence of each zone or cluster of zones identified in the BEM. This was meant to represent the expert's degree of belief in the need for having a separate zone in a given area of the EUS. Thus, in an expert was not absolutely certain that a given area of the EUS needed to be distinguished from its surroundings on the basis of its seismicity characteristics (frequency, and probability distribution of earthquake magnitudes), he would assign a level of confidence of existence smaller than one. For example a level of confidence of existence of 0.5 (50 percent) for a zone A means that in the opinion of the expert he could, with the same level of confidence draw two maps identical in all respects except that one map would have a zone A and the other map would not.

   We used the level of confidence on existence as a probability on the need to have the zone show on the map and we emphatically said that a zone "existed" when it appeared in a map. Thus in the case when a zone is identified with a level of confidence on existence, P, greater than 0.5 and smaller than 1.0 this zone will appear in the B.E.M. However there is a (1-p) probability that his zone should not appear thus we can construct another map where this zone would not appear.

b. In the case described in (a) when considering a possible alternative map built from the BEM by removing from it a zone with a probability of existence greater than 0.5 and smaller than 1.0, the expert needed to specify the characteristics of the area occupied by the zone after it is removed. This was done by identifying which surrounding zone could "fill-up" the hole created by the removal of the zone. We called this surrounding zone the "Host" zone.

   In many cases the host zone was (by default) the CZ. However in many other cases, experts constructed zonation maps where smaller zones with probabilities of existense smaller than 1.0 were embeded within larger zones which naturally became their host zones.

c. Their level of confidence in the shape of each zone or cluster of zones identified in the BEM.

d. An alternative shape of the replacement zone to the zone in (c) above. This replacement zone is named the "alternate" zone.

For purposes of the analysis, all levels of confidence were normalized and treated as probability values.

In order to integrate the experts' uncertainty into the hazard analysis, an uncertainty analysis, based on a simulation process was developed. Each simulation draws a realization of each of the uncertain variables, e.g. zonation, from a probability distribution (this process is described in detail in Bernreuter et al., 1985). For the uncertainty analysis the zonations were treated as random and for the purpose of the simulations a set of all possible maps with associated probabilities were developed based on the set of alternative zonations by the experts. Thus, for each expert, a discrete probability distribution of zonation maps was created. This was accomplished by the program module named COMAP and is schematically described in Fig. C10 where an example of possible maps is given, starting with two zones in the BEM. The fundamental idea used in COMAP consists in starting with the best estimate map, as a set of zones, and performing all of the following operations to generate all possible maps:

a. Remove each zone or combination of zones with probability of existence less than 1.0 (but greater than 0.5) from the BEM and fill the hole so created by their respective host zone. At the same time compute the probability associated with each arrangement of the zones which constitutes these maps.

b. Remove from the BEM each zone or combination of zones with non-zero probability of having an alternate shape (probability of the shape in the BEM not equal to 1.0) and replace them by their respective alternative shapes. At the same time, compute the probability associated with each of these possible cases.

c. Take each of the possible maps defined in (a) and perform the operation in (b) on the remaining zones initially in the BEM, using the convention that when a zone does not exist (i.e., was removed from the BEM), it could not be replaced by an alternate zone. Furthermore, when a cluster of zones is to be replaced by another cluster of zones, this could be performed only if all of the zones of the cluster of zones to be replaced actually existed. All the time is the probability associated with each of these possible cases is computed.

In practice, the process discribed above led to a very large number of maps for most experts. However, the probability associated with a given map decreases very fast, as it becomes more and more different from the BEM.

To be consistent, a map should be selected at random from all possible maps for each simulation. However it was not feasible to implement such a scheme due to the exhorbitant computer core size and computer time that would have been involved. Instead, an approximate (truncated) distribution of the maps was obtained, using the module COMAP, in which the maps with very low probability have been discarded. The assumptions made to finally end up with a manageable number of possible maps, the effects of which were tested to determine their validity, were:

a. The maps (arrangement of zones as described in (a), (b), (c) above) with probability less than 1% of the BEM probability were discarded.

b. The total number of maps was set to a maximum of 30 per seismicity expert.

Since the geometry of some of the host zones changed as a result of the combinations (eliminating a zone or replacing a zone by its alternate), it was necessary to update their PRD (see Sec. C.6.1) This operation was performed on the final set of 30 or less selected maps. This information and the weights (probabilities) associated with each of these maps was then used as the basic geometric input to the program module ALEAS which computes the seismic hazard at the site. ALEAS treats this set of 30 (or less) maps and their associated probabilities as a discrete probability distribution from which it draws in a Monte Carlo simulation process.

C.6.3 Calculation of the Hazard and its Uncertainty Distribution

C.6.3.1 General Considerations

Many of the methods of evaluation of the seismic hazard at a site acknowledge the variable nature of earthquake occurrences and of the ground motion attenuation data. In particular, the SEP study, which preceeded the present one, focused on including such random variation, which we call the "random uncertainty", into the final hazard. There is, however, another type of uncertainty which is more likely to introduce systematic bias into the results. This we call modeling uncertainty. For example, modeling uncertainty is associated with the choice of a zonation map and the choice of a particular ground motion attenuation equation. In the present study considerable effort went into developing a methodology which also include modeling uncertainty into the results. The complexity of the problem made it difficult to express modeling uncertainty by an analytical method and a simulation technique was adopted instead. The details of this technique are described in Bernreuter et al.,1985. This section is only meant to give the reader a general understanding of the method. The overall steps, practical assumptions, and some of the important technical points adopted in the program module ALEAS, which calculates the hazard, are described briefly here.

C.6.3.2 Random and Modeling Uncertainty

Consider a simple hypothetical ground motion attenuation model of the following form,

$$\text{Log PGA} = bM - c \text{ Log } R + E \qquad \text{(C.25)}$$

In this equation b and c are constants, M is the magnitude of an earthquake, R is the distance from the source of the earthquake to the site, and E is a random variable with zero mean and standard deviation σ

With this model, for a given magnitude M and distance R, the PGA can be predicted, but only in terms of a conditional probability statement such as one of the form:

$$P\,[\text{PGA} \geq a \mid M,R] \qquad \text{(C.26)}$$

Given M and R, this probability depends on the distribution of the random variable E which describes the random variation in PGA for different events, all with the same magnitude and at the same distance from the site.

In this example, the constants b, c and σ are fixed and characterize the model of attenuation. The distribution of the random variable E is a model of the random variation in PGA.

Similarly, given that an earthquake has occurred, the magnitude M of the earthquake is variable. The random variation in M is represented by the magnitude recurrence relationship, for example, the Gutenberg-Richter (1956) equation. Theoretically, the knowledge of the ground motion model, the distribution of M with the knowledge of the zonation and seismicity is sufficient to calculate the hazard at a site. Thus, the hazard depends on the models of attenuation and recurrence chosen for the analysis. However, Eq.C.25 is not the only ground motion attenuation model which can be used. That is there may be uncertainty in the ground motion model and/or in the magnitude (or intensity) distribution. Thus, in the present study these uncertainties are identified as modeling uncertainties.

Thus, in our analysis modeling uncertainties are recognized in the following items:

- o Many possible choices of ground motion attenuation models. This includes choices of b, c and σ in the example of Eq. C.25

- o Many possible different conceptual zonations for a given zonation expert.

- o Given a seismic zone specified by an expert, many possible models of earthquake recurrence. This is expressed by a range of values in the parameters of the recurrence equation. In addition, each seismicity expert was given the choice between two differents models of recurrence. The first model called here the "LLNL" model assumes that the linear Gutenberg-Richter relationship applies between two values of magnitude (the domain of validity). Outside of this domain, the recurrence law is extrapolated on the basis of additional assumptions. The second possible choice is the "Truncated Exponential" model.

Given a seismic zone specified by an expert there is uncertainty in the value of the upper limit on the magnitude or intensity of potential earthquakes. This is expressed by a range of values in M_U or I_U.

C.6.3.3 The Method of Simulation

Simulation is used to develop bounds, which describe modeling uncertainty, for the hazard at a site. In this method, the hazard at the site is calculated many times to describe the uncertainty in the hazard, due to the modeling uncertainties described above in the inputs. In each of the calculations a set of the models is chosen and used to calculate the hazard, which for a ground motion parameter A is in the form:

$$P [A > a]$$

Then for each new simulation, a set of new models is chosen.

Let us assume that N_S simulations are performed for each seismicity expert. For each new simulation a zonation map is drawn from the distribution of maps described in Section A3, i.e., if $W_{m1}, W_{m2}, \ldots, W_{mj}, \ldots, W_{mM}$ are the probabilities associated with maps 1, 2, ..., j, ..., M, the expected proportion of the times that the j^{th} map is used is equal to $N_S W_{Sj}$. For each simulation, a ground motion model is selected in the same manner as the maps. The distribution of ground motion models is derived from the input of the Ground Motion Panel experts. Uncertainty in all of the remaining model parameters are defined by continuous analytical functions and for each simulation they are drawn from their respective probability distribution in the usual fashion used in Monte Carlo simulations. These parameters include the earthquake upper magnitude for each zone, the coefficients of the model of earthquake occurrence and the standard deviation of the random variation associated with the ground motion parameter. The probability distributions are determined from the responses of the seismicity and the ground motion experts. Basically, the distribution for each parameter is based on the best estimate, a lower bound and an upper bound provided by the experts.

In the analysis performed in the first phase of this study and described in Bernreuter et al (1984), the random variables "a" and "b" were assumed to be lognormally distributed. This assumption was discussed with the experts at the feedback meetings and further analysis showed that, due to the very high skewness in some cases, it was not applicable. Instead, we selected a triangular distribution for these parameters (a,b). In the extensive sensitivity analysis performed in Bernreuter et al, 1985 we compared the effects of these two distributions. The most important conclusion was the fact that the use of the triangular distribution leads to a greater sample variation than the lognormal probability distribution. As a result adequate stability of the percentile curves can only be achieved by using more simulations when using the triangular distribution.

In the triangular distribution model, the variations in "a's" and "b's", and M_U, the expert's best estimate is equated to the mode and the expert's bounds are similarly considered to be the 2.5 and 97.5 percentiles, as shown in Fig. C.11 where the lognormal and triangular distributions are compared.

C.6.4 Weighted Hazard

The seismic hazard analysis at a site depends on the zonation and seismicity parameters provided by the seismicity experts and the distribution of ground motion models and GMP variation provided by the ground motion experts. Since there were several experts on each of the panels, a hazard calculation, either a best estimate calculation, or a Monte Carlo simulation, can be made for each pair of experts, (i.e. a seismicity expert and a ground motion expert). To describe the seismic hazard at a site, it is reasonable to combine the estimates over all pairs of experts, either to get an overall "best estimate" seismic hazard curve or to descrive the uncertainty, including the variation between experts, in estimating the hazard at a site. When combining hazard estimates over experts it is necessary to consider how the combination is to be achieved. The method used in this study is a weighted combination where the weights are based on self-weights provided by the experts. Only the general concept of the method used is presented here, the details appear in Appendix A, Volume 1 of Bernreuter et al, 1985.

Before discussing the concept of combining over experts, it is appropriate to distinguish the self-weights used in that combination and the "weights" that the ground motion experts associated with the ground motion models (and the "weights" associated with the zonation maps). In the latter case, the weights or level of confidence quantify the experts' degree of belief in the appropriateness of the ground motion models (or zonation map) in describing the attenuation of motion between source and site (or in describing regions of uniform seismicity). These weights are used to define a discrete probability distribution for the ground motion models (or class of zonation maps) which form the basis for selecting models and maps in the Monte Carlo simulation.

With regard to the self-weights, these were developed to reflect how each expert perceives his level of expertise, relative to the overall scientific community, about the seismicity and ground motion modeling, respectively. The relative expertise of the ground motion experts is assumed to be with regard to the applicability of the ground motion attenuation models presented in the ground motion questionnaires and do not depend on the region of the EUS. In the case of the seismicity experts, four regions were identified, as shown in Fig. C.12. These four regions are: Northeast (NE), Southeast (SE), North Central (NC) and South Central (SC). The determination of these regions was also based on the locations of the large scale dominant tectonic models and considerations of attenuation characteristics as described in a study by Singh and Herrmann, 1983. Each seismicity expert was asked to provide his self weights for each of the four regions. These regional self weights are used to compute a single seismicity expert's weight in a way which emphasizes an expert whose self weight is high in the region contributing the most to the hazard at the site. The method then involves one of combining the results over seismicity experts and ground motion experts when the weight associated with each one of them is known. Two cases have to be considered.

Case (a) "Best Estimate" Hazard

The term "best estimate" (BE) is actually a misnomer. In the present context, it refers to the hazard computed with all the parameters of the analysis set equal to the value defined as the best estimate by the experts. In that case the calculation is performed with the best estimate zonation maps, the best estimate upper magnitude cutoffs, best estimate parameters in the definition of the earthquake occurrence and finally the best estimate models including the measure of random variation σ, of ground motion attenuation. The hazard at a given time period, t years, is given by the probability that the maximum PGA in t years, A_t, exceeds the value a. This is expressed by $(A_t >$ and is a combination of the results over all the experts. It is simply obtained by a weighted average, as shown in Eq. C.27 where w_{Au} is the weight for the u^{th} ground motion attenuation expert and w_s is the weight for the s^{th} seismicity expert.

$$\hat{P}_s\,(A_t > a) = \sum_{u=1}^{U} w_{Au}\,\hat{P}_{su}(A_t > a) \Big/ \sum_{u=1}^{U} w_{Au}$$

$$\hat{P}\,(A_t > a) = \sum_{s=1}^{S} w_s\,\hat{P}_s(A_t > a) \Big/ \sum_{s=1}^{S} w_s \qquad \text{(C.27)}$$

In this equation S is the total number of seismicity experts, U is the total number of ground motion attenuation experts andl $P_{su}(A_t \geq a)$ is the "best estimate" hazard for a choice of seismicity S and ground motion expert u. $P_s(A_t > a)$ is the estimated hazard for estimated hazard combined over all seismicity and ground motion experts.

Case (b) Uncertinty Distribution of the Hazard; Derivation of Percentiles
For each pair of experts (s,u), the sth seismicity expert and the uth ground motion experts, the simulation based on the uncertainties in the models, e.g. zonation maps and ground motion models, and the seismicity parameters, e.g. a,b, M_u, produces a set or distribution of values for the hazard $P(A_t > a)$ for a fixed a. This uncertainty distribution is denoted

$$P_{s,u}\{p_a \leq p\}$$

where $p_a = P(A_t > a)$ denotes the hazard, now treated as a random variable because of the uncertainty. The uncertainty distribution for the hazard, combined over all pairs of experts, is taken as the weighted average of the individual distributions $P_{s,u}\{p_a \leq p\}$ using the weights (w_{Au}, w_s). This is expressed in Eq. C.28,

$$P\{p_a \leq p\} = \sum_{s=1}^{S} \sum_{u=1}^{U} w_s w_{Au} P_{s,u}\{p_a \leq p\} \Big/ \sum_{s=1}^{S} \sum_{u=1}^{U} W_S W_{Au} \qquad (C.28)$$

Uncertainty bounds for the hazard, which reflect the uncertainties associated with estimating the hazard at a site, are based on evaluating the percentiles of the uncertainty distribution. The different percentile levels for $P(A_t \geq a)$, for each a, are assessed from the distribution of the hazard in Eq. C.28 This applies, in particular, to the single variable PGA and PGV. In the case of the determination of the Uniform Hazard Response Spectra, the same operation is repeated for each frequency.

To produce corresponding 15th and 85th curves,which reflect the uncertainties in estimating in the hazard curve at a site, the points $p_{.15}(a_i)$, i=1,...I, are combined to form the 15th percentile curve and, correspondingly, the points $p_{.85}(a_i)$ are combined to form the 85th percentile curve.

One must be careful in interpreting the bounds as hazard curves which correspond to a specific set of input parameters. The bounds are analogous to the bounds which are used to define Uniform Hazard Spectra (UHS). The UHS is the locus of points each corresponding to the same probability of exceedance and does not represent a distinct spectrum since the inherent physical correlation between the values at different frequencies has been lost in the calculations. However, it can be interpreted as an envelope of all possible spectra. Similarly the 85th and 15th percentile hazard curves do not represent the hazard curve corresponding to a specific set of input parameters. Rather they are the locus of hazard values, such that the "Probability" in the hazard exceeding that value is greater than .85 (or .15) for each a. It can be interpreted as an envelope of all possible hazard curves. It is not correct to interpret the 85th percentile curve as a hazard curve which will not be exceeded by 85 percent of the hazard curves produced by the uncertain parameters. It is true, however, that for a fixed value a the value $P_{.85}(A > a)$, taken from the 85th percentile curve at a, is an estimate of the value of $P(A > a)$ which has "degree of belief" or "confidence" 0.85 that it will not be exceeded, where the "confidence" is a weighted average of the level of confidence of the individual experts.

C.7 REFERENCES

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2. Bernreuter, D.L., J.B. Savy, R.W. Mensing, J.C. Chen, and B.C. Davis, "Seismic Hazard Characterization of the Eastern United States", UCID-20421, Vol. 1 and 2, April 1985.

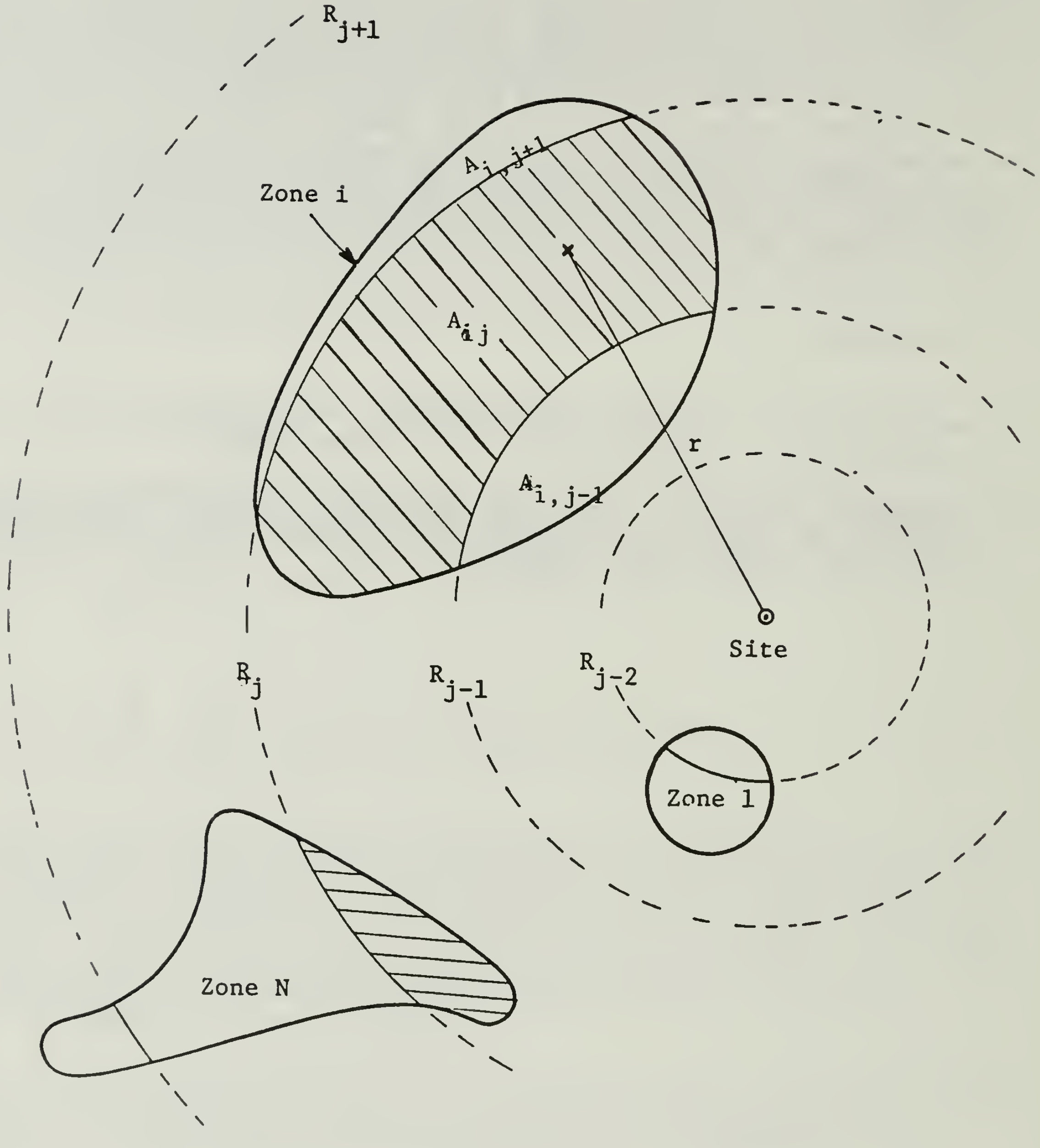


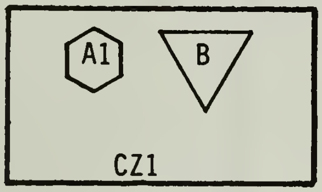
Figure C.9 Distance Distribution for a Zone

Assume an expert's zonation map includes two zones plus the complementary zone:

- Zone A has a probability of existence equal to 1.0, and can take two different shapes A1 and A2 with probability .6 and .4 respectively.
- Zone B has a probability of existence equal to .7, and therefore a probability of nonexistence equal to .3. Zone B has only one possible shape.

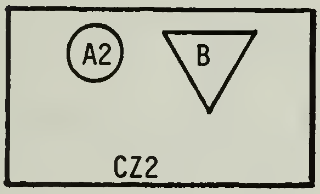
Four maps can be generated with respective weights w_1, w_2, w_3 and w_4.

MAP 1:



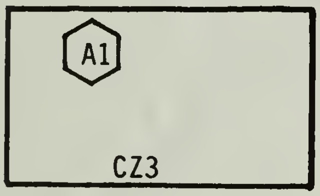
BEM ,{A1, B,CZ1} $w_1 = (.7)\ (.6) = .42$

MAP 2:



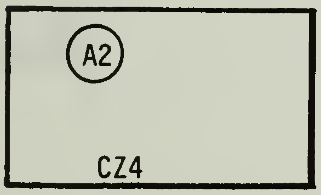
{A2, B,CZ2} ; $w_2 = (.7)\ (.4) = .28$

MAP 3:



{A1, CZ3} ; $w_3 = (.3)\ (.6) = .18$

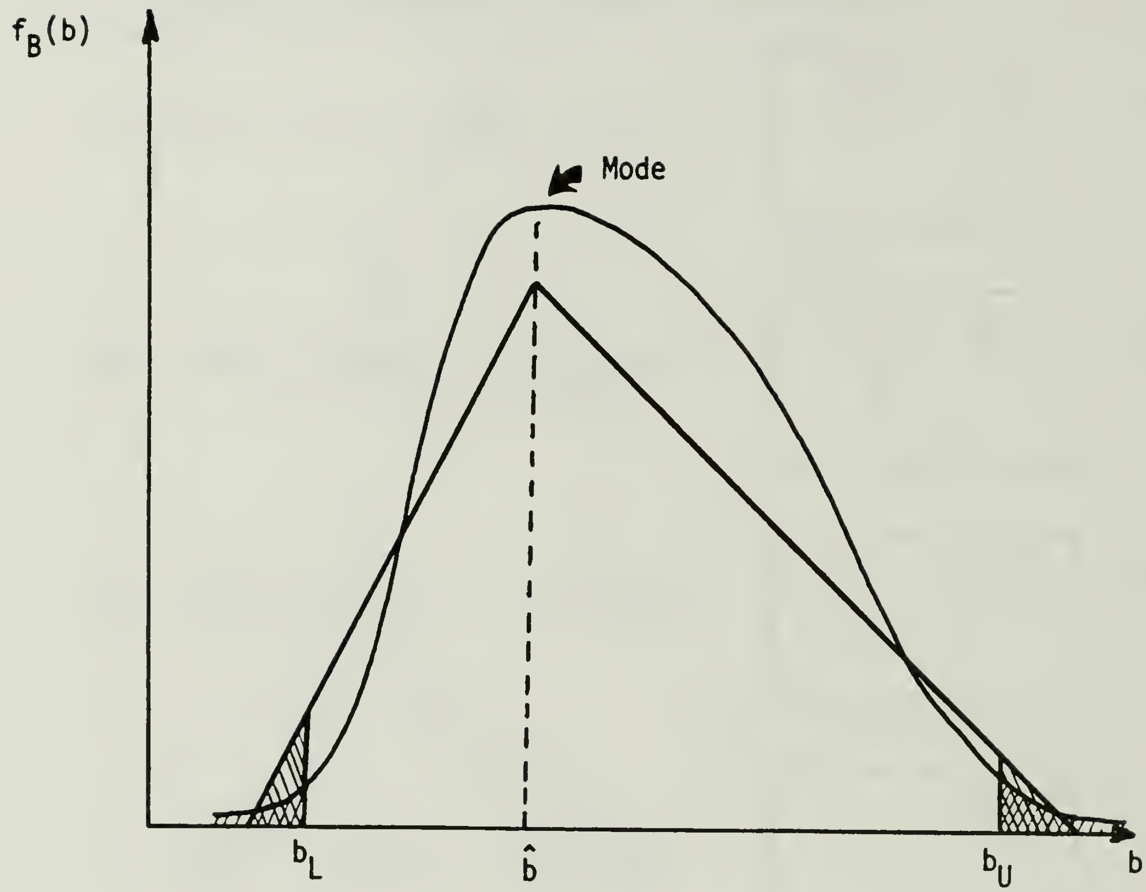
MAP 4:



{A2, CZ4} ; $w_4 = (.5)\ (.4) = .12$

The complementary zone CZ is different for each of the four cases. It plays the role of the Host zone for A1,A2 and B.

Figure C.10 Example of Generation of Possible Maps



$$P\ [b_L < b \leq b_u] = .95$$

Figure C.11 Estimation of the Uncertainty Probability Distribution of Parameter B.

The best estimate $\hat{b}$, probided by the expert is equated to the mode, b_L is taken as the 2.5th percentile and b_U as the 97.5th percentile of the distribution, where b_L and b_U are the lower and upper bounds provided by the expert.

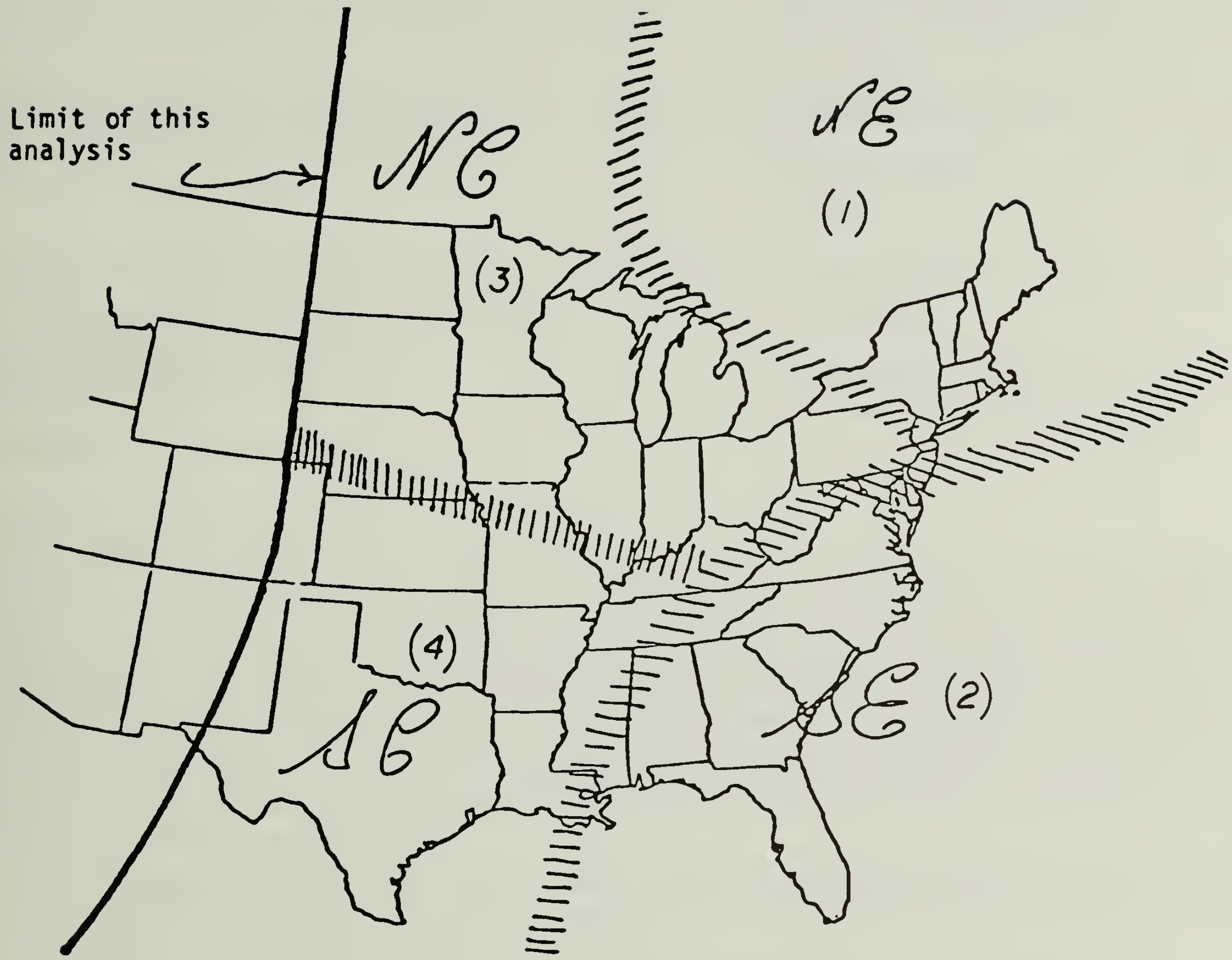


Figure C.12 Identification of four regions of the Eastern U.S. based on a compilation of the seismic zonation expert maps developed in this study and a map of Q_{0}- contours from Singh & Herrmann (1983).

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13. ABSTRACT (200 words or less)

The EUS Seismic Hazard Characterization Project (SHC) is the outgrowth of an earlier study performed as part of the U.S. Nuclear Regulatory Commission's (NRC) Systematic Evaluation Program (SEP). The objectives of the SHC were: (1) to develop a seismic hazard characterization methodology for the region east of the Rocky Mountains (EUS), and (2) the application of the methodology to 69 site locations, some of them with several local soil conditions. The method developed uses expert opinions to obtain the input to the analyses. An important aspect of the elicitation of the expert opinion process was the holding of two feedback meetings with all the experts in order to finalize the methodology and the input data bases. The hazard estimates are reported in terms of peak ground acceleration (PGA) and 5% damping velocity response spectra (PSV).

A total of eight volumes make up this report which contains a thorough description of the methodology, the expert opinion's elicitation process, the input data base as well as a discussion, comparison and summary volume (Volume VI).

Consistent with previous analyses, this study finds that there are large uncertainties associated with the estimates of seismic hazard in the EUS, and it identifies the ground motion modeling as the prime contributor to those uncertainties.

The data bases and software are made available to the NRC and to the public uses through the National Energy Software Center (Argonne, Illinois).

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